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Landscape Metrics to Assess Habitat Suitability for Conservation Bird Species in the Southeastern United States

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Preface

This study was conducted by Dr. Linda Peyman Dove, Environmental Systems Branch (ESB), Ecosystem Evaluation and Engineering Division (EEED), Environmental Laboratory (EL), Vicksburg, MS, U.S. Army Engineer Research and Development Center (ERDC).

This report is a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy from Mississippi State University, Mississippi State, MS.

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At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

CHAPTER I

INTRODUCTION

Biodiversity is declining at an alarming rate. Although it is difficult to quantify the historical rate of species loss, scientists generally agree that current extinction rates far exceed those found in the geologic record (Probst and Crow 1991).

The impact of human alteration of the natural landscape on species habitat is a key destructive force leading to this decline of biodiversity. The adverse impact of human activities is not limited to simply the destruction of a species habitat. Fragmentation of the habitat that remains can also have profound effects depending on when and how the habitat is fragmented. Species that are found in the remaining habitat fragments often become isolated from other populations and suffer from adverse effects of changes in the surrounding landscape. Hence, habitat fragmentation is a major concern relating to biological diversity (Harris 1984, Saunders et al. 1991) and is an example of how changes in the specific spatial parameters of a habitat within a landscape can be important to species survival. The effect of habitat fragmentation on biological diversity is an important consideration in the conservation of the Earth's resources because of detrimental effects on biodiversity and the distribution and abundance of individual species. However, the degree to which a given species is affected by

habitat fragmentation is dependent on a complex interaction of the habitat requirements of the species and the shape, size, and makeup of the fragmented habitat.

Conservation of the biological diversity of a landscape would be facilitated if there was a way to determine the impact of habitat changes on species of interest. Presently there is no good way to assess or quantify the impact of landscape changes to habitat suitability, even for species of conservation priority. The research presented here attempts to provide this capability for conservation priority Neotropical and resident songbirds found in fragmented landscapes of the southeastern United States, utilizing existing data sources, geographical information system and spatial analysis software. This research is now feasible due to recent innovations in computer and remote sensing technologies that have reduced computation expenses, provided new sources of spatially extensive data, and provided the impetus for the development of new spatial analysis software.

Existing land use and land cover spatial data are widely available and can potentially be used to evaluate the impact of changes in the landscape on species of conservation priority. The scale of the data varies and selection of a data source is complicated by the fact that there is no single best scale for determining landscape changes to habitat suitability. The scale depends on the question asked, the species and habitats involved, and the processes believed to be important (Wiens 1989).

Two existing and publicly available datasets provide an opportunity for development of methods in this area. They are the USGS Land Use Land Cover (LULC) and the Breeding Bird Survey (BBS) data sets. The USGS LULC dataset is a kilometer-

resolution remotely sensed dataset that utilizes a uniform classification scheme for the entire country. The BBS is a broad scale bird population survey dataset that covers the United States and Canada. The BBS is the only survey of this scope and apparently has never been used in quantifying landscape habitat suitability for bird species.

Objective

The objective of this research was to use the BBS and USGS LULC data to determine if kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability for Neotropical and resident songbirds. The study area covers a block of the Southeastern USA, which included 90%, 30%, and 30% of Alabama, Georgia, and Florida respectively (Figure 1). It includes 15 bird species listed by Southeast Partners in Flight as a conservation priority (Table 1) (Hunter 1998). This study focused on determining the utility of existing data in predicting bird abundance and evaluating the sensitivity of predictive models to varied size of landscape units analyzed.

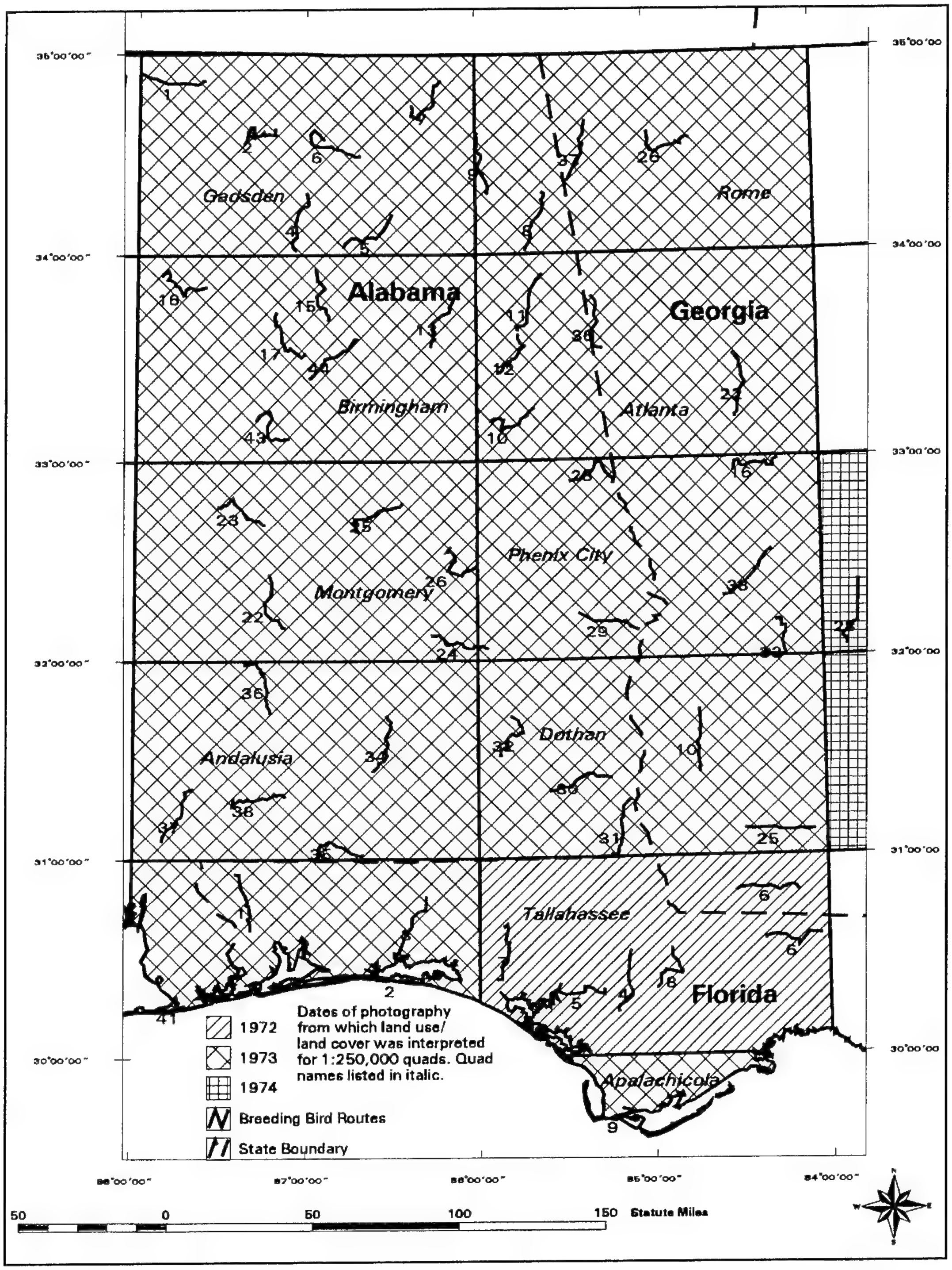


Figure 1. Study area boundary, dates of photography from which USGS land use/land cover data were interpreted, and breeding bird survey routes.

Table 1. Conservation priority bird species under study in this research, the American Ornithologist Union (AOU) number and the species preferred habitat.

Species Name	AOU No.	Habitat
Prairie Warbler	6730	Abandoned fields, cut over burned over woods, woodland margins
Northern Bobwhite	2890	Abandoned fields, brushy areas, hedgerows, thickets, woodland margins, open woods
Field Sparrow	5630	Favor scattered saplings or shrubs in weedy habitats, overgrown fields, woods margins, hedgerows, and thickets
Loggerhead Shrike	6220	Open country, open fields, pastures, cultivated fields where there are scattered trees for nesting and telephone wires or fences for perching
Eastern Kingbird	4440	Open country, prefer areas with scattered trees, fences, telephone wires, and fields
White-eyed Vireo	6310	Dense thickets, especially where moist, common habitats are stream side shrubbery, swamp borders and openings, willow thickets, and damp tangles
Eastern Wood-pewee	4610	Open to medium-growth forests and woodlots, favor neither pines nor hardwoods
Yellow-throated Vireo	6280	Wide variety of woodlands, favor mature deciduous trees in fairly open setting, especially where moist, avoid pure coniferous forests, open hardwoods, woodland borders, extensive forest
Hooded Warbler	6840	Primarily in deciduous forests but also in mixed forests, favor moist forests with a fairly dense understory, such as bottomlands, rich woods, and ravines. Sometimes in the deciduous understory of mature pine forests, interior species
Wood Thrush	7550	Deciduous or mixed forests with a fairly well-developed deciduous understory, especially where moist, interior species
Yellow-billed Cuckoo	3870	Deciduous forests, bottomland woods, woodland thickets, other hardwood forest, generally avoid coniferous woods, extensive forest
Kentucky Warbler	6770	Rich, moist deciduous forests, bottomland forests,, seldom in conifers, area sensitive, interior specie
Brown-headed Nuthatch	7290	Pines, prefer mature, open pinewoods
Prothonotary Warbler	6370	Bottomlands forests, almost always near standing water, prefer swamps that are somewhat open with scattered dead stumps, extensive willow thickets near lakes or ponds, interior species
Brown-headed Cowbird	4950	Open woods, margins, thickets, farmyards and residential areas

CHAPTER II

LITERATURE REVIEW

An extensive literature review was conducted to determine the current state-of-art in the assessment of the impact of landscape changes on habitat suitability. The review was useful in garnering information on the promising techniques utilized in past studies as well as valuable background information that provides context for the current effort. The discussion of the literature is presented in three parts. First, information is presented that is applicable to studies relating species to landscape structure. Second, a comprehensive review of spatial pattern metrics found in the literature is presented, including information on the specific metrics used in this research. Third, a detailed review of those landscape level studies of associations of horizontal spatial pattern to bird abundance that are specifically pertinent to this study is provided. The definition of some of the more specialized terms used in this discussion can be found in Table 2.

Relating Species to Landscape Structure

Habitat patches are distributed within landscapes and their spatial patterns may exert influence on the abundance, distribution, and dynamics of vertebrate populations inhabiting those landscapes (Wiens 1976, 1989). The spatial configuration of a

Table 2. Specialized Terms and Definitions

Fragmentation - an external disturbance that alters the large patch, thus creating isolated or tenuously connected patches of the original habitat, interspersed with an extensive mosaic of other habitat types (Wiens 1989). There are two components associated with fragmentation: reduction in the total area of a habitat type, and apportionment of the remaining habitat into smaller, more isolated patches (Saunders et al. 1991, Harris 1984).
Landscape - a heterogeneous land area composed of an interacting mosaic of habitat patches (Forman and Godron 1986).
Landscape ecology - the study of the structure, function and change in the landscape composed of interacting ecosystems. It provides the basis for studies directed at investigating associations dealing with landscape structure (Forman and Godron 1986).
Landscape scale or Broad scale - refers to a large area such as a landscape. Landscape varies in size down to a few kilometers in diameter (Forman and Godron 1986).
Landscape structure – composition and spatial configuration of the patches within a landscape. Landscape composition considers the presence and amount of each patch type within the landscape but does not address the location of patches within the landscape. Spatial configuration refers to the physical distribution or spatial character of patches within the landscape.
Local scale or Fine scale – refers to a small area such as a patch. It includes between-plot and within-plot studies. Localized areas of a few meters or hundreds of meters across are at a finer scale than a landscape (Forman and Godron 1986).
Patch - a nonlinear surface area differing in appearance from its surroundings.
Spatial scale - refers to the spatial size or the ratio of length on a map to true length. Spatial scale of datasets involve both grain and extent. Grain refers to the resolution of the data, that is the area represented by each data unit. Extent refers to the overall size of the study area (Turner et al. 1989).

species habitat affects populations by influencing the patterns of movement of individuals, interactions among individuals, and exposure to factors associated with the edge of habitats (Wiens 1976, 1989). Landscape ecology attempts to provide quantitative measures of landscape structure. Quantitative measurements of landscape structure are a necessity in the empirical investigation of landscape structure and bird species associations.

The hypothesis that landscape structure plays an important role in the habitat suitability for populations has come, in part, from field studies on forest fragmentation (Saunders et al. 1991). Fragmentation of habitats has received much attention, especially in agricultural areas where natural vegetation is broken into small, isolated patches as land is converted for human use. The majority of work by ecologists has focused on the fragmentation of forests (e.g. Harris 1984), possibly because forest habitat loss is so visible and the recovery period so long (Wiens 1989).

How different bird species respond to habitat fragmentation is determined by their individual spatial requirements and affinity for edge versus interior locations in habitat patches. A difference in individual area requirements is the most obvious factor in their response. Minimal-area requirements among species have been documented in numerous studies (e.g. Lynch 1987, Robbins et al. 1989). In most cases, the determination of minimal area requirements is based on the presence or absence of a species in habitat fragments of different sizes. A species response to fragmentation is also based on its affinity for edge versus interior habitats. As the size of a habitat patch is reduced by

fragmentation, the proportion of the fragment that adjoins other habitat types (edge) increases (Forman and Godron 1986). Studies based on the eastern deciduous forests of North America show that the abundance of vertebrate species associated with forest interiors usually declines, while the abundance of vertebrate species specializing on forest edges increases in response to forest fragmentation caused by agricultural development and urbanization (Whitcomb et al. 1981, Robbins et al. 1989, Terborgh 1989). Changes in vegetation, food resources, predation, brood parasitism, and competition have been noted as causes of the observed vertebrate community changes (Kroodsma 1982, Brittingham and Temple 1983). In North America, neotropical migratory songbirds are thought to be particularly vulnerable to habitat fragmentation, since they breed primarily in extensive stands of mature, floristically diverse forest (Rosenberg et al. 1999). Extensive stands of mature forest protect from the proximity to a habitat edge, especially for the single-brooded low-nesting neotropical migrants (Whitcomb et al. 1981). Since nest parasitism by Brown-headed Cowbirds decreases with distance away from the forest edge, and since Brown-headed Cowbird breeding is concentrated around the period when neotropical migrants are nesting, these species are especially vulnerable to nesting failure as a result of Brown-headed Cowbird activity.

Most studies on fragmentation have employed a patch-centered sampling scheme in which independent forest patches, not landscapes, were sampled (e.g. Rosenberg and Raphael 1986, Lehmkuhl and Ruggiero 1991). Based on the relationships developed between species abundance or richness and a number of patch characteristics, such as patch size, inferences were made about how landscape structure affects wildlife

populations. It is unclear however, whether relationships derived at the patch level can be extrapolated to the landscape level.

Focusing exclusively on fragmentation of habitat patches, however, neglects the fact that it is often the structure of an entire landscape mosaic rather than the size or shape of individual patches that is important to birds (Wiens 1989). The likelihood that dispersal can occur between fragments is influenced by the configuration of the fragments and the landscape mosaic in which they are located. Fragments of habitat are not surrounded by totally inhospitable environments, as are oceanic islands. Even if patches are completely isolated from areas of similar habitat, the dynamics of their populations may be influenced by features of the surrounding habitats or distances to other patches of the same habitat (Wiens 1989). Thus, the spatial juxtaposition of habitats is an important landscape consideration and can best be examined by landscape-level studies which have not been adequately addressed in previous studies of habitat suitability.

The more recent studies found in the literature show a trend towards broadening the spatial scope of study. This has entailed going from an emphasis on local-scale processes to the inclusion of processes influencing plant and animal populations that occur at a variety of spatial scales, including the landscape scale. One advantage of landscape-level studies of species-habitat associations is the expanded spatial dimension and the connections to other landscapes. Studies at these broader scales can be used to understand the spatial connections present, and to more effectively manage the broader ecosystem. It should be emphasized the limited geographic scope of most forest

fragmentation studies stems from the inherent difficulty in surveying large land areas in a limited time frame (Rosenberg et al. 1999).

Spatial Pattern Metrics

A landscape is distinguished by the spatial relationships between its component parts. Landscape structure is determined by both the composition and configuration of a given landscape. Composition considers the presence and amount of each patch type within the landscape but does not address the location of patches within the landscape. Configuration refers to the physical distribution or spatial character of patches within the landscape (McGarigal and Marks 1994). Spatial pattern metrics are used to quantify the horizontal landscape structure. They can be grouped as: 1) area metrics, 2) core area metrics, 3) patch density and size metrics, 4) edge metrics, 5) shape metrics, 6) diversity metrics, and 7) interspersion/juxtaposition metrics. Since the metrics typically are highly inter-correlated, several studies have used principal component analysis to develop independent factors (McGarigal and McComb 1995, Pearson 1993, Rosenberg et al. 1999). The specific metrics employed in this study were selected based on their successful use in past studies and documentation in the literature. A discussion of each metric group is presented below. The mathematical equations used to calculate the specific metrics used in this study are also provided. Table 3 provides definitions of symbols and subscripts used in the equations. Three sample sites used in this study were selected to provide graphic examples of the metrics. The three sample sites were selected

Table 3. List of Symbols and Subscripts

Subscripts	**Definition**
i	= 1, … ,m or m' patch types (classes)
j	= 1, … ,n patches
k	= 1, … ,m or m' patch types (classes)
q	= 1, … ,p disjunct core areas
s	= 1, … ,n patches, within specified neighborhood
Symbols	**Definition**
A	= Total landscape area (m^2).
a_{ij}	= Area (m^2) of patch ij.
a_{ijs}	= Area (m^2) of patch ijs within specified neighborhood (m) of patch ij.
a_{ij}^c	= Core area (m^2) of patch ij based on the specified buffer width (m).
p_{ij}	= Perimeter (m) of patch ij.
p_{ijk}	= Length (m) of edge of patch ij adjacent to patch type (class) k.
E	= Total length (m) of edge in landscape; includes landscape boundary and background edge segments if the user decides to treat boundary as edge; otherwise, only boundary segments representing true edge are included.
E'	= Total length (m) of edge in landscape; includes entire landscape boundary and background edge segments regardless of whether the represent true edge.
e_{ik}	= Total length (m) of edge in landscape between patch types (classes) i and k; includes landscape boundary segments representing true edge only involving patch type i.
e'_{ik}	= Total length (m) of edge in landscape between patch types (classes) i and k; includes all landscape boundary and background edge segments involving patch type i, regardless of whether they represent true edge.
e''_{ik}	= Total length (m) of edge in landscape between patch types (classes) i and k; includes entire landscape boundary and background edge segments, regardless of whether they represent true edge.
d_{ik}	= Dissimilarity (edge contrast weight) between patch types i and k
N	= Total number of patches in the landscape, excluding any background patches.
N'	= Total number of patches in the landscape that have nearest neighbors.
$n = n_I$	= Number of patches in the landscape of patch type (class) i.
$n' = n'_i$	= Number of patches in the landscape of patch type (class) i that have nearest neighbors.
n_{ij}^c	= Number of disjunct core areas in patch ij based on specified buffer width.
M	= Number of patch types (classes) present in the landscape, excluding the landscape border if present.
m'	= Number of patch types (classes) present in the landscape, including the landscape border if present.
m_{max}	= Number of patch types (classes) present in the landscape.
h_{ijs}	= Distance (m) from patch ij to nearest neighboring patch of the same type (class), based on edge-to-edge distance.
g_{ik}	= Number of adjacencies (joins) between pixels of patch types (classes) I and k.
P_i	= Proportion of the landscape occupied by patch type (class) i.

as they have varying degrees of forest fragmentation and illustrate a range in value for the metrics.

1) Composition

Area metrics quantify landscape composition. The area of the patches comprising a landscape is perhaps the single most important piece of information contained in the landscape (McGarigal and Marks 1994). Patch area has ecological utility, as shown by the considerable evidence that bird species occurrence, abundance and richness are strongly correlated with patch size (Robbins et al. 1989). Knowing how much of the landscape is comprised of a particular patch type is an important measure in ecological applications. For example, in forest fragmentation there is often a quantitative loss of habitat. Thus, in studies of forest fragmentation, it is important to know how much habitat exists within the landscape. Also, even though many vertebrate species that specialize on a habitat have minimum area requirements (e.g. Robbins et al. 1989), not all species require the habitat to be in one contiguous patch. The Northern Spotted Owls have minimum area requirements for late-seral forest that varies geographically, but individuals use late-seral forest that may be distributed among many patches (Forsman et al. 1984). Thus, late-seral forest area might be a good index of habitat suitability within landscapes the size of Northern Spotted Owl home ranges (Lehmkuhl and Raphael 1993).

It is often desirable to quantify area in relative terms as a percentage of the total landscape area. Relative area or percent of the landscape can be determined with the equation:

$$\%LAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}^{c}}{A}(100) \tag{1}$$

Figure 2 depicts 3 sample landscapes that vary in the amount and pattern of agricultural land, deciduous forest, evergreen forest, mixed forest, and forested wetlands. Site A is the most fragmented site, relative to the original forest, while site C is largely forested. Site B is intermediate. The dynamics of some ecological processes are likely to be quite different in the 3 landscapes. For example, populations of organisms associated with forest land are likely to be much smaller in landscape A and perhaps subject to a higher probability of local extinction than in either landscape B or C.

Forest area is particularly important to vertebrate abundance. Robbins et al. (1989) found, from 15 variables, percent forest most often related to bird relative abundance. Robinson et al. (1995) found strong correlations between percent forest cover and nesting success for most species studied, more so than the correlation with percent forest interior, and mean forest patch size.

2) Core Area

Core area is the area within a patch beyond a specified edge or buffer distance. The core area indices integrate into a single measure the affects of patch area, patch

shape, and edge effects. Thus, even though they quantify landscape composition they are also affected by landscape configuration. The primary significance of core area of patches in a landscape appears to be related to the edge effect. Some birds, for example, are adversely affected by predation, competition, and brood parasitism along forest edges. Core area has been found to be a better predictor of habitat quality than patch area for these forest interior specialists (Temple 1986). Core area is affected by patch shape, while patch area is not affected by shape. Therefore, even if a patch is large enough to support a specific species, it may not contain enough suitable core area to support the species.

Core area metrics may be useful in the study of habitat fragmentation since fragmentation affects both habitat area and configuration (McGarigal and Marks 1994). At the same time, these indices confound the effects of habitat area and configuration. As an example, if the percent of a landscape that is comprised of core area is small, it indicates that there is little core area available, but it does not discriminate between a small amount of the patch type and a large amount of the patch type in a highly fragmented configuration. Thus, core area indices are usually best interpreted in conjunction with other area indices that provide a better overall picture of the landscape structure (McGarigal and Marks 1994).

Core area indices are affected by the specified edge width. Since the edge width dictates the core area, the index is meaningful only if the specified edge width is relevant to the research study. Also, the utility of the core area metrics as compared with the area metrics is dependent on the minimum patch size and edge width used. If the minimum

patch size is large but a very small edge width is used, the core area and area metrics will be nearly identical. Thus the core area indices will be relatively insensitive to differences in patch size and shape.

The total core area index (TCAI) quantifies core area for forest land as a percentage of total forest land. The equation to calculate TCAI is listed below.

$$TCAI = \frac{\sum_{j=1}^{n} a_{ij}^{c}}{\sum_{j=1}^{n} a_{ij}}(100) \tag{2}$$

The TCAI represents the landscape along a continuum from most to least fragmented (McGarigal and Marks 1994). Figure 3 depicts 3 sample landscapes that vary in the amount and pattern of core forest land based on a 250 meter edge width from the forest edge. According to this index, only about 14% of the forest land in landscape A is considered interior habitat; thus, the remaining 86% is edge habitat. Forest land in landscape B is 50% interior habitat and 50% edge, while 72% of the forest land in landscape C is interior and the remaining 28% is edge. Without any other information, it could be deduced that the forest land in landscape A is highly fragmented. It is useful to know the percent of the landscape comprised of forest land to know if the TCAI for landscapes B and C comprise a large or small part of the landscape. For example, knowing that landscapes B and C are composed of approximately 61% and 77% forest respectively, it is apparent that the 50% and 72% of these areas that are considered core area represent substantial land areas.

Core area is important to vertebrate abundance or occurrence. Temple (1986) found total core area to be highly correlated to bird species abundance, more so than the correlation with the total area of forest.

3) Patch Density

Metrics representing the number or density of patches and the average size of patches are not spatially explicit measures but are usually best considered as representing landscape configuration. Patch density (PD) has the same utility as the number of patches index, except that patch density presents the number of patches on a per unit area basis allowing comparisons among landscapes of varying size. The number or density of patches of a particular habitat type may affect a variety of ecological processes. For example, in species that are exclusively associated with a single habitat type, the patch density may influence the number of subpopulations in a spatially dispersed population. The number of subpopulations could influence the dynamics and persistence of the metapopulation (Gilpin and Hanski 1991). The number of patches or patch density can affect the stability of species interactions and opportunities for coexistence in predator-prey and competitive systems (Kareiva 1987). Also, the number of patches or patch density illustrates habitat subdivision which may affect the spread of disturbances across a landscape (Franklin and Forman 1987). For example, patch types that are more subdivided might be more resistant to disturbances such as disease and fire than contiguous patch types; however, they may have higher rates of disturbance for disturbances such as windthrow (McGarigal and Marks 1994).

The equation used to calculate PD is listed below.

$$PD = \frac{n_i}{A}(10{,}000)(100) \qquad (3)$$

Figure 4 depicts 3 sample landscapes that vary in the amount and pattern of forest land. PD indicates that the forest land is more subdivided in landscape A than landscape C.

Patch density is important to bird abundance. McGarigal and McComb (1995) found a component defined by patch density to be significant to certain species abundance, while components depicting patch size and patch shape did not show a significant association to the bird species abundance.

4) Patch Size

As discussed in the area metrics, the area of the patches comprising a landscape is one of the most important pieces of information contained in the landscape (McGarigal and Marks 1994). The average size comprised by each patch type is also important. Progressive reduction in the size of habitat fragments is a key component of habitat fragmentation. Therefore, a landscape that has a smaller average patch size than another landscape is considered more fragmented.

Mean patch size represents the average size of all patches of a particular type within the landscape. It is derived from the number of patches but does not convey any information about how many patches are present in the landscape. Since a mean patch size of 5 ha could represent 1 or 50 patches, which could have important ecological

implications, it is probably best interpreted along with patch density (McGarigal and Marks 1994).

The minimum patch size and the extent of the image influence the mean patch size. Patches are often subdivided by the extent boundaries (McGarigal and Marks 1994).

The equation used to calculate MPS is listed below.

$$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left(\frac{1}{10{,}000}\right) \tag{4}$$

Figure 4 depicts 3 sample landscapes that vary in the amount and pattern of forest land. MPS attempts to rank the 3 landscapes with respect to forest land fragmentation, with A being most fragmented and C being the least fragmented. The examples used in Figure 4 have dramatic differences in MPS. By interpreting the MPS with patch density, it is evident that landscape A was very fragmented, with small numerous patches while landscape C was not very fragmented, having a smaller number of large patches.

The average patch size of forest patches is important, particularly to wildlife management. Howell et al. (2000) found a high correlation between forest interior bird species abundance and mean size of forest patches, more so than percent forest and edge density.

5) Edge Density

Edge metrics are considered to best represent landscape configuration, even though they are not spatially explicit. The amount of edge in the landscape is pertinent to various

ecological criteria, such as that of wildlife abundance. The forest edge effect is due to the landscape having differences in wind and light intensity that reaches the forest patch which, in turn alters the microclimate and disturbance rates (e.g., Ranney et al. 1981). The patch shape and orientation and the adjacent land cover affect the proportion of the patch that is affected by edge. A large round patch has a minimal amount of edge habitat while a large convoluted patch may be primarily edge habitat. It is generally accepted that edge effects are viewed from an organism perspective, since species usually have either an affinity, adversity, or are unaffected by edge (McGarigal and Marks 1994).

Studies have suggested that changes in vegetation, predation, brood parasitism, and competition along forest edges has resulted in the reduction of populations of various vertebrate species dependent upon forest interiors (e.g. Robbins et al. 1989, Wilcove 1985).

Edge density (ED) standardizes edge to a per unit area basis so that comparisons among landscapes of varying size can be made. The index is affected by the resolution of the image. The greater the detail with which the edges are delineated, the greater the apparent edge length. For example, in images with a coarse resolution, edges may mostly appear as straight lines, while with finer resolutions, the edges may appear as more convoluted lines. Edge metrics developed from images with different resolutions should not be compared.

The equation used to calculate ED is listed below.

$$ED = \frac{\sum_{k=1}^{m'} e_{ik}}{A}(10{,}000) \tag{5}$$

Figure 4 shows 3 sample landscapes that vary in the amount and pattern of forest land. ED is highest in landscape A. For a species that requires forest land edge habitat, ED might be used to model habitat suitability. In this case, landscape A would be most suitable while landscape C would be least suitable.

Edge density is important in determining response by vertebrates to forest fragmentation or the edge and interior of forests. Rosenberg et al. (1999) found a strong relationship between the chance of detecting Brown-headed Cowbirds and potential nest predators and highly fragmented sites that had high edge density or large amounts of edge. This response of Brown-headed Cowbirds and potential nest predators was opposite that of Tanagers.

6) Mean Shape Index

Shape metrics quantify landscape configuration in terms of the complexity of the patch shape. Patch shape is possibly as important as patch size; however, there is relatively little information about the effects of shape on the ecosystem (Forman and Godron 1986). Patch shape is important in the dispersal and foraging of organisms. For example, birds flying over woods, are more apt to find a long narrow clearing that is oriented perpendicular to their direction of movement, while they may miss a round clearing (Forman and Godron 1986). The long narrow clearing parallel to their

movement may also be missed. Patch shape has been shown to influence inter-patch processes such as small mammal migration (Buechner 1989). However, the primary significance of the shape of patches in a landscape appears to be related to the edge effect.

One method of quantifying patch shape is by assessing the complexity of the patch shape compared to a standard circular shape. The shape index is minimum if the patch is circular and increases as the patches become noncircular. This shape index is widely applicable and used in landscape ecological research (Forman and Godron 1986). The mean shape index (MSI) measures the average perimeter-to-area ratio for a specific patch type. This shape index is limited in the same way as the edge indices in reference to the differences between how lines are portrayed in vector and raster images. The perimeter-to-area ratio method in assessing shape, is insensitive to differences in form and structure or patch morphology (McGarigal and Marks 1994). Patches may have different shapes, but may have identical areas and perimeters and shape indices. This index is not useful as a measure of patch morphology, but is best considered as a measure of overall shape complexity. This index represents the average patch shape for a specific habitat, and thus does not necessarily fully describe the shapes of patches in a landscape if the distribution of patch shapes is complex.

The equation used to calculate MSI is listed below.

$$MSI = \frac{\sum_{j=1}^{n}\left(\frac{p_{ij}}{2\sqrt{\pi \circ a_{ij}}}\right)}{n_i} \tag{6}$$

Figure 4 shows 3 landscapes that vary in the amount and pattern of forest land. The MSI values for all 3 landscapes are greater than 1, indicating the average patch shape in all 3 landscapes is noncircular. The forest land patches in landscapes B and C (least fragmented) are most irregular, while the patches in landscape A (most fragmented) are least irregular in shape. These results indicate that human-induced fragmentation in landscape A caused a simplification in patch shapes compared to the geometrically complex patch shapes found in the more natural, unaltered landscapes B and C.

The shape of forest stands and openings is particularly important for wildlife, because habitat conditions and shape are often closely interrelated (Marcot and Meretsky 1983). Palmer et al. (2000) even used MSI in a highly dynamic streambed landscape and found MSI to be linked to faunal abundance. Garrabou et al. (1998) found MSI to be one of the most suitable indices for describing its spatial pattern in rocky benthic communities.

7) Diversity

The diversity metrics quantify landscape composition. Diversity measures have been used in a variety of ecological applications, such as measures of plant and animal species diversity. They are commonly used in community ecology. Diversity measures are influenced by richness and evenness, with richness pertaining to the number of patch types present and evenness pertaining to the distribution of area among different types. Some indices are more sensitive to richness while others are more sensitive to evenness. The actual species composition of a community is not provided in the diversity indices. For example, a community could have high species diversity and be comprised primarily

of common or undesirable species. Or, a community could have low species diversity and be comprised of rare species.

Two common diversity indices are the Simpson's diversity index and Shannon's diversity index. Simpson's diversity index (SIDI) is less sensitive to richness and therefore places more weight on the common species. Shannon's diversity index is more sensitive to richness and thus places more weight on rare species. A wide variety of diversity indices have been used to measure landscape composition (O'Neill et al. 1988, Turner 1990). SIDI was used in this study.

The value of SIDI represents the probability that any patch type selected at random would be different types. The higher the value, the greater the likelihood that any two randomly drawn patches would be different patch types or greater diversity.

The equation used to calculate SIDI is listed below.

$$SIDI = 1 - \sum_{i=1}^{m} P_i^2 \tag{7}$$

Figure 5 shows 3 landscapes that vary in composition and pattern. The SIDI represents the landscapes along a continuum from most to least diverse. The diversity of landscapes A and B is similar, while landscape C is more diverse. In landscape A, SIDI indicates that there is a 54% probability that 2 randomly chosen patches would represent different patch types.

Species diversity of a landscape patch appears to be mainly determined by habitat diversity and the disturbance regime (Forman and Godron 1986). In using SIDI to

determine effects of landscape fragmentation on bird communities, it was found that continuous forest landscapes supported more species than did fragmented landscapes McIntyre (1995).

8) Interspersion and juxtaposition

Interspersion and juxtaposition metrics quantify landscape configuration. Each patch is evaluated for adjacency with all other patch types. The interspersion index measures the extent to which patch types are interspersed, not necessarily dispersed. Higher values result from landscapes in which the patch types are well interspersed or equally adjacent to each other. Lower values characterize landscapes in which the patch types are poorly interspersed. The index is not directly affected by the number, size, contiguity, or dispersion of patches. The interspersion index is a relative index that represents the observed level of interspersion as a percentage of the maximum possible given the total number of patch types (McGarigal and Marks 1994).

The equation used to calculate IJI is listed below.

$$IJI = \frac{-\sum_{i=1}^{m'}\sum_{k=i+1}^{m'}\left(\left(\frac{e_{ik}}{E}\right)\circ\ln\left(\frac{e_{ik}}{E}\right)\right)}{\ln\left(1/2\left[m'(m'-1)\right]\right)}(100) \tag{8}$$

Figure 5 shows 3 landscapes that vary in composition and pattern. The IJI values indicate that the interspersion of available patch types is greatest in landscape C and least in landscape B. This probably occurs because landscape B has patch types that are very small, thus the distribution of edge lengths among the unique patch types is more uneven.

IJI is used in a variety of purposes. Hunziker (1999) found the IJI measures correlate significantly with landscape preference values in terms of illustrating landscape fragmentation. Kean et al. (1999) used IJI to measure landscape pattern in areas that have burned and found fire influences landscape pattern by creating more fragmented, and disconnected landscapes.

Horizontal Spatial Pattern Related to Bird Abundance

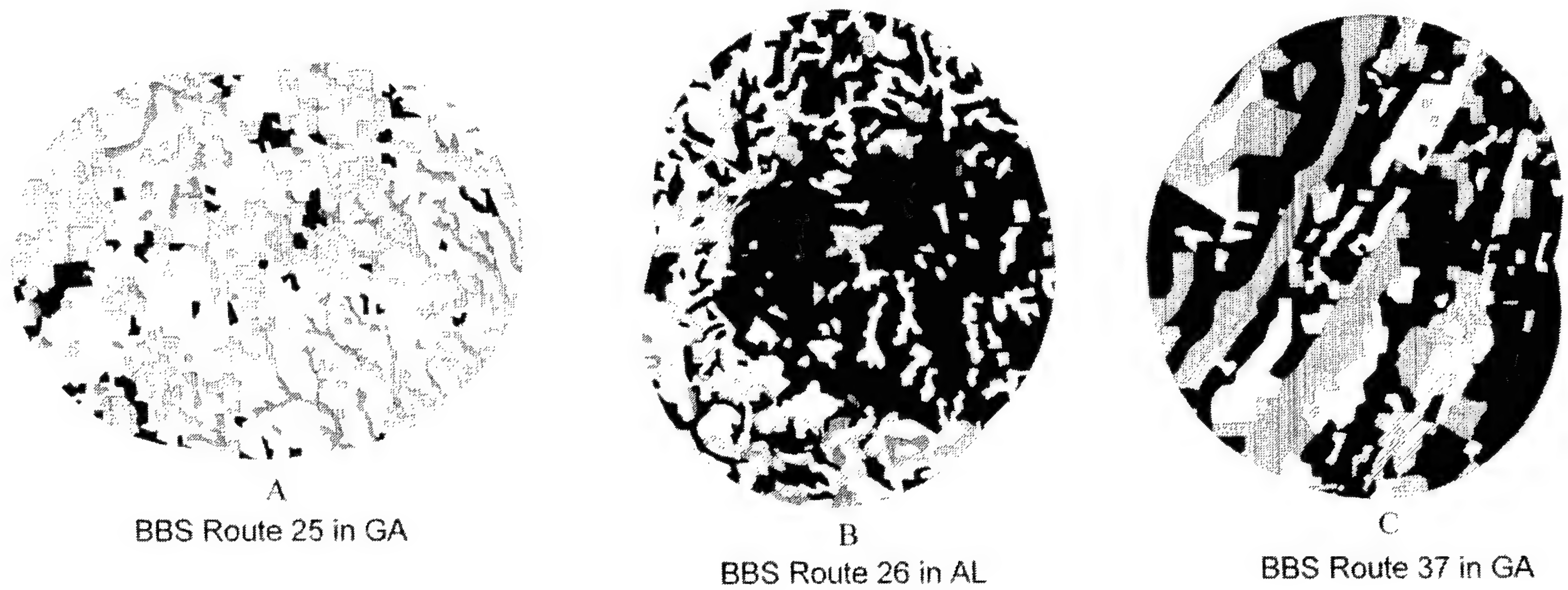
Songbirds are an almost ideal subject for investigating the potential use of spatial metrics in the evaluation of habitat suitability. Songbirds have the advantage of being widely dispersed and are known to be sensitive to the same landscape changes that can be remotely sensed, and for which data are widely available. In the relatively sparse literature existing on this subject there is general agreement that area metrics (e.g., percent forest cover) provide a simple first approximation for exploring habitat suitability. Several studies report good correlations with the relative amount of suitable habitat area and bird success (Robinson et al. 1995, Pearson 1993, Robbins et al. 1989, Roberts and Norment 1999, Knick and Rotenberry 1995). However, total area may be less important than its distribution within the landscape. The Robinson et al. (1995) study notes that nesting success of the birds studied was positively correlated with forest area but that forest area was autocorrelated with percent forest interior. A high percent forest interior discourages predatory Brown-headed Cowbirds and offers a better biological explanation of the bird success than forest area alone. Thus core forest area has become a popular indicator for interior forest species (Temple 1986, Donovan et al. 1997, McGarigal and McComb 1995). Some Neotropical migrant forest-interior birds

have displayed an adverse sensitivity to the creation of edges within large forest interiors, indicating that they are limited by edge zones rather than forest fragment size (Germaine et al. 1999). Proximity to a habitat edge may greatly reduce the desirability of a portion of a forest, especially for the single-brooded low-nesting neotropical migrants (Whitcomb et al. 1981). Donovan et al. (1997) found that the extent of edge effects in nest predation in the central United States was related to the degree of habitat fragmentation. Rates of predation on artificial nests were high in both edge and core forest habitat in highly fragmented landscapes, and low in both habitats in unfragmented landscapes. Significant edge effects were found in moderately fragmented landscapes, where rates of predation were high along edges and low in the core habitat. Heske et al. (1999) also found that medium-sized, generalist mammalian predators on songbird nests reach their highest population densities in fragmented landscapes with abundant edge habitat, particularly agricultural edges. The increased nest predation and parasitism in combination with isolation from other forests may reduce both the rates of return by adult birds and colonization by first-time breeders (Robbins et al. 1989). These points argue for the consideration of patch shape and interspersion, as well as patch size and area. It has been demonstrated that the area of forest interior increases at a steeper rate than edge, for nearly square or circular patches (Levenson 1981). Contrary to forest interior species, the distribution of some bird species may be insensitive to area metrics due to a dependence on edge (Bolger et al. 1997, Rosenberg et al. 1999).

Since many landscape metrics are highly correlated with each other, principal components analysis has been used to deal with the problems associated with

multicollinearity. Various studies have utilized this technique in addressing the issue of autocorrelation and have been successful in developing meaningful factors that can be used to describe the components of the landscape (McGarigal and McComb 1995, Osborne 1984, Rosenberg et al. 1999).

From reviewing these analyses it is clear that the appropriate approach for quantifying habitat suitability will vary from species to species depending upon their particular environmental adaptations. Also, there may be cases where species are insensitive to variation in the landscape. For example, generalist species utilize a variety of habitat types, so the landscape effect is weaker than for more specialized species (Pearson 1993). A specific example is the Northern Parulas (*Parula americana)* which are relatively insensitive to variation in landscape structure but are highly sensitive to arboreal poison ivy (Robins et al. 1989). While landscape structure is just one of many possible limitations to bird success, it is certainly an important factor and is perhaps the one most under human control.



Land cover type	A	B	C
% Agriculture land	65.62	33.45	19.94
% Deciduous land	7.74	0.78	19.10
% Evergreen land	11.58	2.14	7.53
% Mixed forest	5.37	56.44	49.87
% Forested wetland	5.47	1.40	0.00

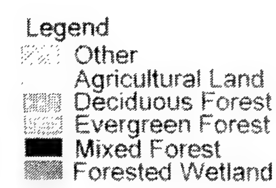
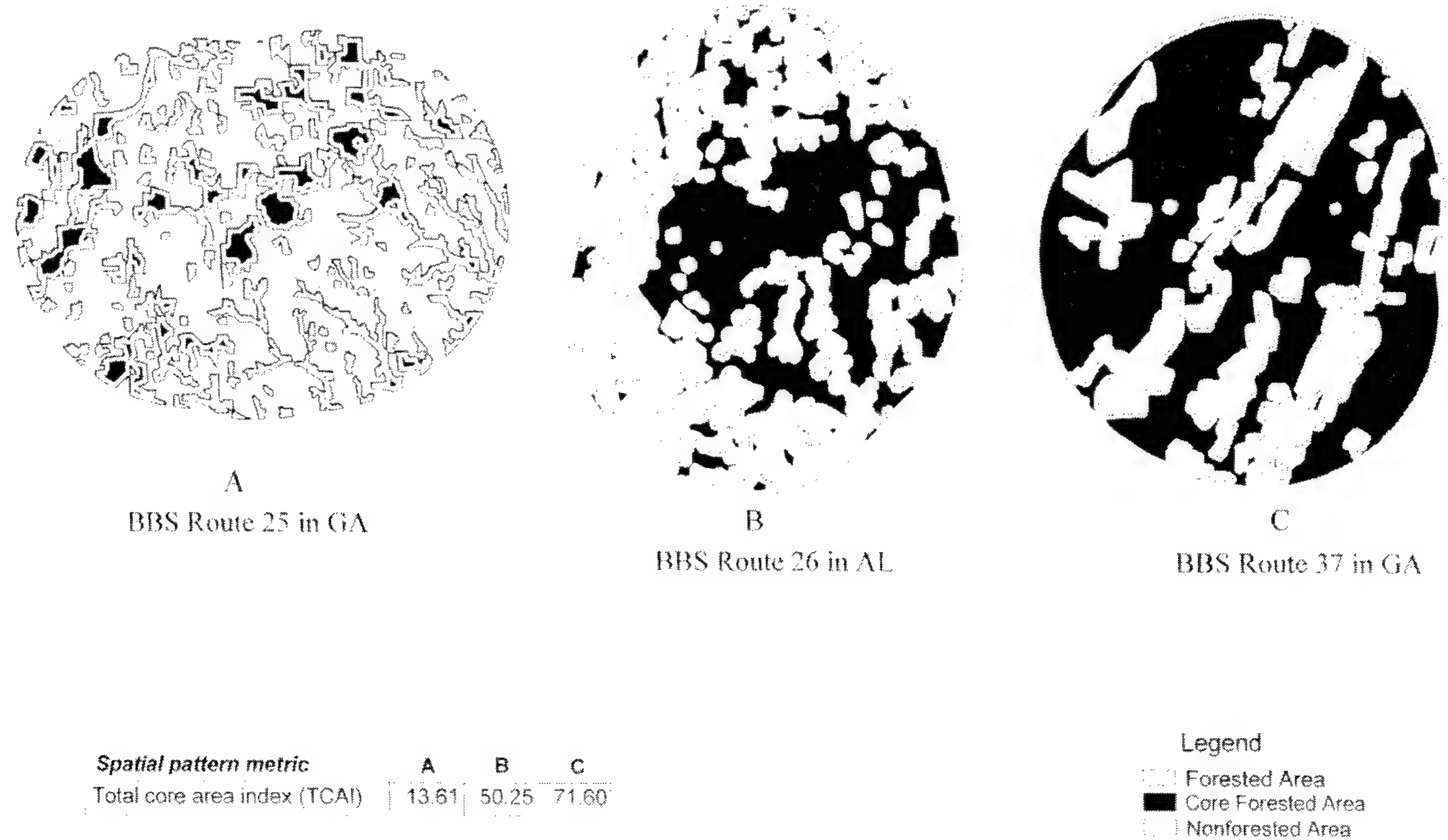


Figure 2. Landscape composition metrics for three sample landscapes that vary in the amount and pattern of agriculture and forest land.

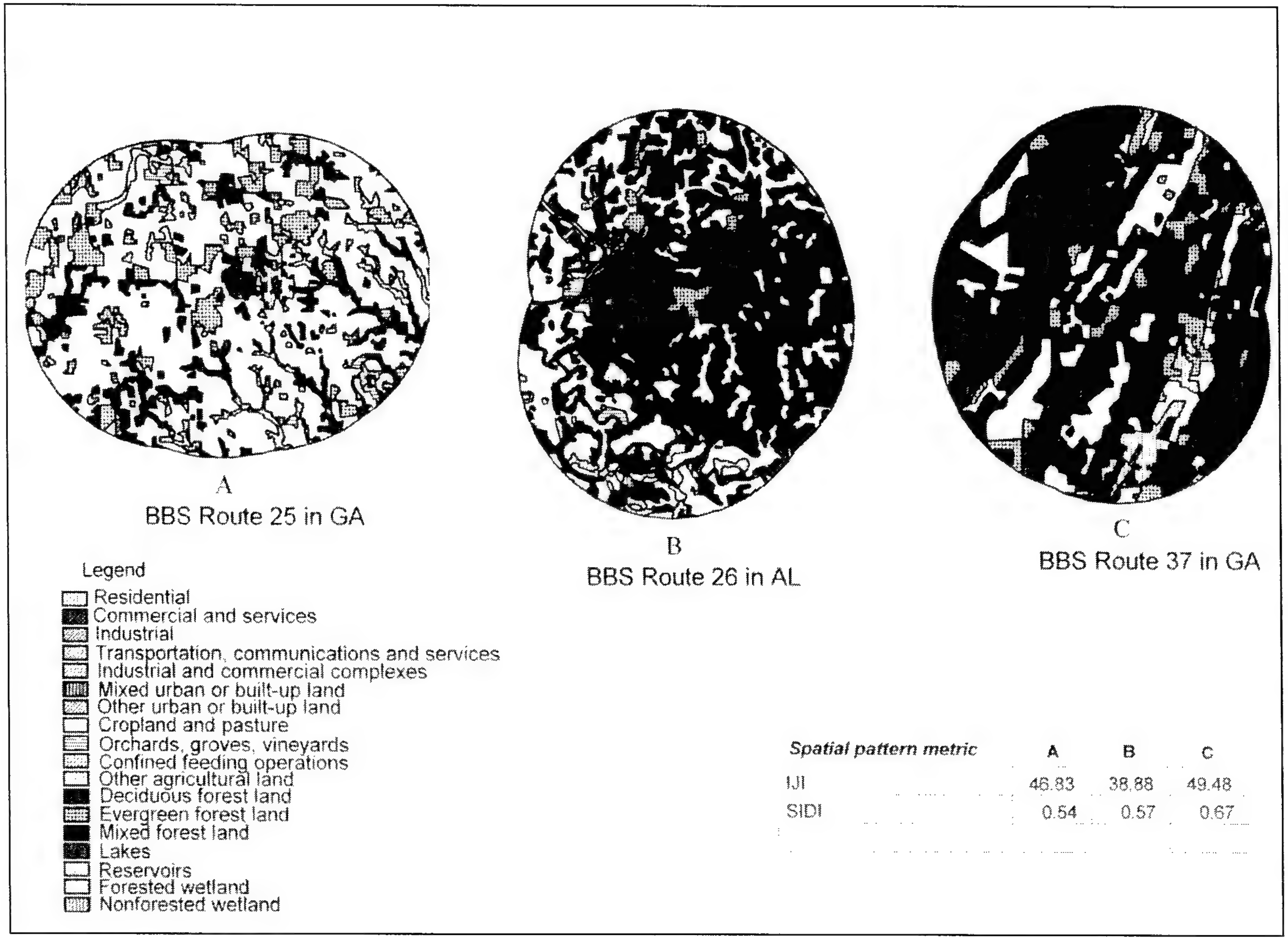


Spatial pattern metric	A	B	C
Total core area index (TCAI)	13.61	50.25	71.60

Figure 3. Total core area index for three sample landscapes that vary in the amount and pattern of forest land.

Spatial pattern metric	A	B	C
Mean patch size (MPS)	106.10	635.81	4952.67
Patch density (PD)	0.28	0.10	0.02
Edge density (ED)	16.11	13.45	7.20
Mean shape index (MSI)	1.65	1.85	1.84

Figure 4. Spatial pattern metrics for three sample landscapes that vary in the amount and pattern of forest land.



Spatial pattern metric	A	B	C
IJI	46.83	38.88	49.48
SIDI	0.54	0.57	0.67

Figure 5. Interspersion and juxtaposition index (IJI) and Simposon's diversity index (SIDI) for three sample landscapes.

CHAPTER III

METHODS

Study Design Overview

The objective of this research was to use the BBS and USGS LULC data to determine if kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability for Neotropical and resident songbirds. The mean count of each bird /route was calculated using BBS data. This was done for 15 bird species and 3 bird groups for the 53 BBS routes shown in Figure 1. The landscape structure was quantified using a suite of 12 spatial metrics calculated from USGS LULC data for each of the 53 BBS routes. The metrics for all routes were pooled and summarized into broad landscape structure components using principal components analysis (PCA) techniques. Multiple regression techniques were used to determine if kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability.

The 15 species selected for inclusion in this research (Table 1) were identified as conservation priority species in prior research, Partners in Flight (Hunter 1998). The designation of a species as a conservation priority species indicates that its situation can be considered as particularly precarious and that it should be the focus of conservation efforts. According to the BBS data the incidence of most of these species has been declining, either on an overall basis or in localized areas (Appendix A). Habitat loss or

the fragmentation of existing habitat is often cited as a primary reason for this population decline. However, this belief is usually based on intuitive opinion or on local level studies. While habitat loss and fragmentation may indeed be the root cause of the decline, there is not a sufficient empirical basis, at the landscape level, to provide a useful understanding of this relationship. Presently there is no reliable procedure for assessing or quantifying the impact of landscape changes on habitat suitability, even for these conservation priority species.

This research effort is based on the premise that conservationists need a method of determining landscape level indicators of habitat suitability for these conservation priority species and that such a method can be developed using the existing the BBS and USGS LULC data. Specifically conservationists need horizontal spatial pattern metrics that provide indicators of habitat suitability for these bird species.

Out of the over 30 breeding or resident landbirds listed by Partners in Flight as conservation priority for this study area, 14 were selected. The Brown-headed Cowbird, which is not a conservation priority specie, was also included since it has been studied and found to be associated with nesting success. All the conservation priority species were assessed, but only those that were well represented on the BBS routes in the study area were included in this study. The criterion for selection was the birds presence on approximately two thirds of the BBS routes. This eliminated species that are typically poorly sampled by the BBS, such as nocturnal birds, seabirds, shorebirds, and raptors (Hepinstall and Sader 1997). After eliminating the species that were not well represented or typically poorly sampled, 14 bird species remained. These 14 species represent habitat

preferences that range from forested areas to successional scrub. The majority of the species are Neotropical migrants, with a few resident bird species.

The development of quantitative data describing landscape structure required the selection of landscape spatial pattern metrics and the determination of the physical extent on which these metrics were to be calculated. The landscape spatial pattern metrics selected for this study are listed in Table 4. They are a representative sample of metrics from the broad categories of area, core area, patch density and size, edge, shape, diversity and interspersion metrics. These landscape spatial pattern metrics were calculated for four physical extents around each BBS route. Figures 6 and 7 show a typical BBS route and the four extents around a BBS route, respectively. The four extents were defined by a narrow (0.4 km) and wide (10 km) radius buffer around each full BBS route as well as a narrow and wide buffer around each BBS internal 5 mile sub-segment. These sub-segments are referred to as partial routes (Figure 6).

A detailed description of the methods used in this research is presented in the remaining sections of this chapter. Figure 8 shows a schematic outline of the sequence of procedures used to develop the quantitative data and then to determine the efficacy of kilometer-resolution horizontal spatial pattern metrics as indicators of habitat suitability. The procedures in the schematic outline are abbreviated (i.e. (P1) indicates the first procedure). These abbreviations are used in the text so that one can easily locate the procedure in the overall project design. The SPSS software was used for all statistical analyses (SPSS 1998) and the Environmental Systems Research Institute (ESRI 1998) ARC/INFO GIS software was used for all GIS database development and analysis

procedures. The FRAGSTATS Spatial Pattern Analysis Program for Quantifying Landscape Structure was used, in conjunction with ARC/INFO, to calculate the spatial pattern metrics.

Breeding Bird Survey Data

The BBS is conducted by volunteers along secondary roads, randomly selected within degree blocks of latitude and longitude. Each BBS route is approximately 40-km long and consists of 50 stops spaced 0.8 km apart (Sauer et al. 1996). All birds seen or heard within a 0.4 km radius during three minutes are recorded. Each survey route is run during the peak of the breeding season, with certain guidelines for time of day and weather conditions intended to reduce biases in the data (Robbins et al. 1986, Peterjohn and Sauer 1993).

The records for each BBS route included each species American Ornithologist Union (AOU) number and the number of individuals observed for the first ten stops, second ten stops, third ten stops, fourth ten stops, and fifth ten stops, and for the full BBS route (Robbins et al. 1986). It is these 5, 10-stop summaries or 5 mile subsegments that form the basis of the 5 partial BBS routes, and together, the full BBS route. A diagram of a typical BBS route is shown in Figure 6. There were 53 full BBS routes used in this study: 33 in Alabama, 9 in Florida, and 11in Georgia. And with each of the 53 full BBS routes broken into 5 partial routes, this resulted in 265 partial BBS routes in the study.

Using a minimum of 3 years of BBS data, the mean yearly abundance for each species was developed for each partial and full BBS route (Figure 8, Step P1). The mean yearly abundance was calculated by adding the abundance of the species for each year

that data were available (3-5 years) for each route or partial route and dividing by the number of years of data.

The 5 years of data included in this study correspond to the year of the photography from which the USGS LULC were interpreted, as well as the two years prior to and two years after the date of the photography. The additional non-photograph years of data were included to reduce undue variation from extraneous factors such as severe weather. Data from only 3 or 4 years were used for some BBS routes as not all BBS routes had data for the appropriate 5 years. Table 5 shows the years (from 1970-1976) of BBS data used to develop the mean count of birds/route for each species.

The mean count data were used to place each bird into a high, medium, and low abundance category for each route. The birds were categorized using the same criterion as was used in the development of range maps for birds across the South (Hamel 1992). In the development of range maps for birds of the South, Hamel utilized BBS data from 1966-1985. Hamel determined the highest mean count of birds/route across the South (Table 6). Areas with at least 30 % of the peak value are considered High, those with at least 10% are considered Medium, and those with at least 5% of peak value are considered Low Abundance. This same methodology was applied to mean count of birds/route developed for this study. Categorizing bird abundance in this manner allows for the differentiation between the relative abundance of a given species in different areas. This in turn provides the means of differentiating horizontal spatial pattern metric values that should be good indicators of habitat suitability for Neotropical and resident songbirds based on sites with high abundance.

Bird species were also grouped into three categories in order to study the horizontal spatial pattern metric values that are suitable indicators of habitat utilization. The groups included: edge and scrub plus field-edge bird species, forest interior/edge bird species, and forest interior bird species. These groups were based on habitat utilization bird groups developed by Whitcomb et al. (1981). The mean count of birds/route for these groups were developed by adding the following bird species:

- Forest Interior Bird Species
  - Hooded Warbler
  - Kentucky Warbler
- Forest Interior/Edge Bird Species
  - Wood Thrush
  - Prothonotary Warbler
  - Eastern Wood Pewee
  - Yellow-throated Vireo
  - Yellow-billed Cuckoo
  - White-eyed Vireo
  - Brown-headed Nuthatch
- Edge and Scrub plus Field-Edge Bird Species
  - Prairie Warbler
  - Loggerhead Shrike
  - Field Sparrow
  - Eastern Kingbird
  - Northern Bobwhite
  - Brown-headed Cowbird

Physical Extent of Spatial Pattern Analysis

A GIS coverage of each BBS route was developed using USGS DLG data at a scale of 1:100,000 (U.S. Geological Survey, 1989) (Figure 8, Step P2). Each full BBS route was divided into 5 equal parts that represented the 5 partial BBS routes. The full BBS route and the 5 partial routes served as the basis on which the narrow and wide buffers were developed (Figure 8, Step P3) (Figure 7). The narrow buffer had a 0.4 km radius, the distance that a surveyor can hear or see a bird at a BBS stop. The wide buffer had a 10 km radius, a width used in prior research (Robinson et al. 1995). As used in this report, the term "Extent 1" is a 0.4 km radius buffer of a full BBS route; "Extent 2" is a 10 km radius buffer of a full BBS route; "Extent 3" is a 0.4 km radius buffer of each partial BBS route; and "Extent 4" is a 10 km radius buffer of each partial BBS route. The physical area of each extent for each BBS route varied somewhat, since the BBS routes had different shapes. Typically, the area for Extent 1 was 3100 ha and was comprised of an average of 50 patches; Extent 2 was 100,000 ha and was comprised of an average of 370 patches; Extent 3 was 675 ha and was comprised of an average of 13 patches; and Extent 4 was 45,000 ha and was comprised of an average of 174 patches. Figure 7 illustrates each extent. Note that there is a small overlap in the buffer areas for Extent 3 and a large overlap in the buffer areas for Extent 4.

US Geological Survey Land Use Land Cover Data

The physical extents defined above were overlain USGS LULC data. The USGS provides LULC data in digital format in 1:250,000 quadrangles, each covering an area of 1 degree of latitude by 2 degrees of longitude. The USGS LULC quadrangles in the

study area were interpreted from NASA U2/R8-57 high altitude aerial photography taken in 1972, 1973, and 1974 (US Geological Survey 1990). Figure 1 shows the outline and name of the USGS 1:250,000-scale quadrangles and the estimated date of the photography from which they were interpreted. Twelve 1:250,000 quadrangles were used to incorporate all BBS routes.

The USGS LULC data represent a national classification scheme that has achieved widespread acceptance and is being used in a number of operational mapping programs (Avery and Berlin 1992). Table 7 lists the patch types in Level I and II of the USGS LULC dataset (Fegeas et al. 1983). Each polygon in the LULC dataset is referred to in this report as a "patch". The patch type is a descriptive term attached to each patch, or basic unit that makes up the landscape (Urban et al. 1987). All patch types have a minimum polygon size of 16 ha, except urban, built-up land, water, confined feeding operations, other agricultural land and strip mines, quarries, and gravel pits, which have a minimum polygon size of 4 ha.

For each of the twelve 1:250,000 quadrangles of digital LULC data, two different ESRI Arc/Info GIS coverages were developed. In the first coverage, the original Level II patch types were retained (Figure 8, Step P4). In the second coverage, the deciduous forest, mixed forest, evergreen forest, and forested wetland patch types were reclassified into a general patch type called forest, with all line segments depicting the original boundaries between the different forest patch types removed (Figure 8, Step P5). Once the two GIS coverages were developed for each USGS LULC quadrangle, the 4 physical extents defined above, were extracted from the coverages (Figure 8, Step P6).

Spatial Pattern Metrics

FRAGSTATS Spatial Pattern Analysis Program for Quantifying Landscape Structure (McGarigal and Marks 1994) was used to calculate the landscape spatial pattern metrics separately for each of the 4 extents around each BBS route (Figure 8, Step P7). Table 4 lists pertinent information about each metric, including whether it describes composition or configuration, its range in value, a description of how the metric is calculated, and the patch type on which the calculation was based.

As shown in Table 4, the composition metrics, percent agriculture, percent deciduous forest, percent evergreen forest, percent mixed forest, and percent forested wetland, were based on specific level II patch types. The configuration metrics, mean patch size, total core area index, patch density, edge density, and mean shape index, were based on the generalized forest patch type. The metrics developed for the entire landscape mosaic where all patch types were considered simultaneously were Simpson's diversity index (SDI) and the interspersion/juxtaposition index (IJI). Table 4 shows that these metrics were based on all level II patch types.

The configuration metrics, MPS, TCAI, PD, ED, and MSI, were developed on the generalized forest patch type. This was done for several reasons. First, one of the intents of the study was to determine if there was an association of bird species with landscape forest fragmentation, not fragmentation of each specific forest patch type. Secondly, had the specific forest patch types been used, this would have resulted in a total of 27 metrics. Summarizing this many metrics into meaningful components would have proven difficult. Finally, had the specific forest categories been used, many individual study

sites would have been eliminated from subsequent statistical analyses. This was due to the fact that "0" is not a valid value for configuration metrics such as PD, MPS, and MSI. These metrics are always greater than "0" if the patch type is present. If the patch type is not present, a "no data" value is produced. A "no data" value would eliminate the site from statistical analyses. Since forested wetlands and deciduous forest patch types were absent from many of the study sites (Table 8), these sites would have been eliminated from subsequent statistical analyses.

For the area metrics, though, “0” is a valid value. Hence, the composition metrics were based on the more specific forest patch types as well as the cropland and pasture patch type. The literature documents examples of using specific as well as general forest categories to develop landscape spatial pattern metrics (e.g. Robinson et al. 1995, McGarigal and McComb 1995); however, the decision is dependent on the research objective.

Database Statistical Analysis

Two statistical approaches were used in this research study: principal components analysis (PCA) and stepwise multiple regression. The SPSS was used for all statistical analyses (SPSS 1998). Many of the 12 landscape spatial pattern metrics are known to be highly correlated with one another. A principal components analysis was used to simplify the structure of the spatial metric data sets by reducing them to a smaller set of uncorrelated variables that accounted for a large part of the variation in the original data set. A PCA is often useful in reducing the amount of data and is helpful in interpreting

the results. Principal components analysis often reveals relationships that were not previously suspected, and so allows interpretations that would not ordinarily result (Johnson and Wichern 1992).

Four PCAs were conducted, one for each of the 4 study extents (Figure 8, Step P8). The resulting principal component matrix was then transformed by Varimax Rotation. This transformation maximizes the correlation between the PCs and original variables, thus facilitating interpretation (SAS Institute 1988).

The second statistical analysis method used was stepwise multiple regression. Stepwise multiple regression regresses one variable on a set of variables in an exploratory way, to obtain a minimum of unexplained residual variance in terms of the smallest number of variables from the data set (Osborne 1984). The bird species abundance data were regressed against the calculated principal component scores resulting from the PCA to determine if kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability for Neotropical and resident songbirds. A separate multiple regression analysis was conducted on the 4 extents by regressing each bird species on the PCs (Figure 8, Step P9) and each habitat utilization group of bird species on the PCs. This resulted in a total of 72 multiple regression analyses.

For models with the highest R^2 value, logistic regression was used to examine the relationship between the factors and the probability of medium-high species' mean count/route. In this analysis, the dependent variable, assumes a value of 0 if the species was on a route with low or accidental abundance, and 1 if it was on a route with medium or high abundance.

Climate Data

An analysis of background climate data for the study area was conducted. EarthInfo Environmental Database Summary of the Day climate data were used to develop background climate data for the study timeframe and a longer period of record timeframe (EarthInfo 1998). These data were used as a means to determine if the weather during the study timeframe was atypical. This information is listed in Appendix B.

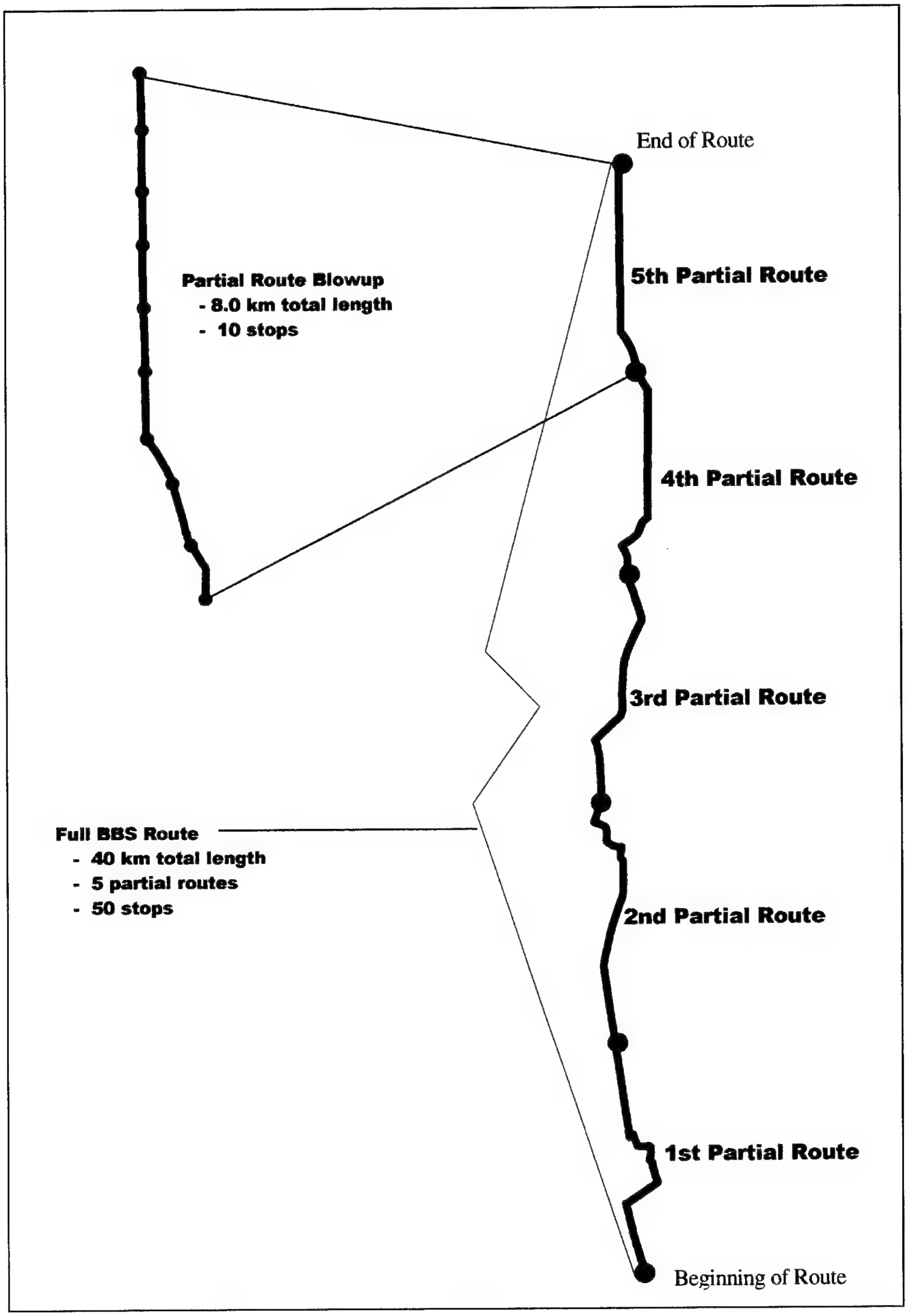


Figure 6. Diagram of a full and partial BBS route.

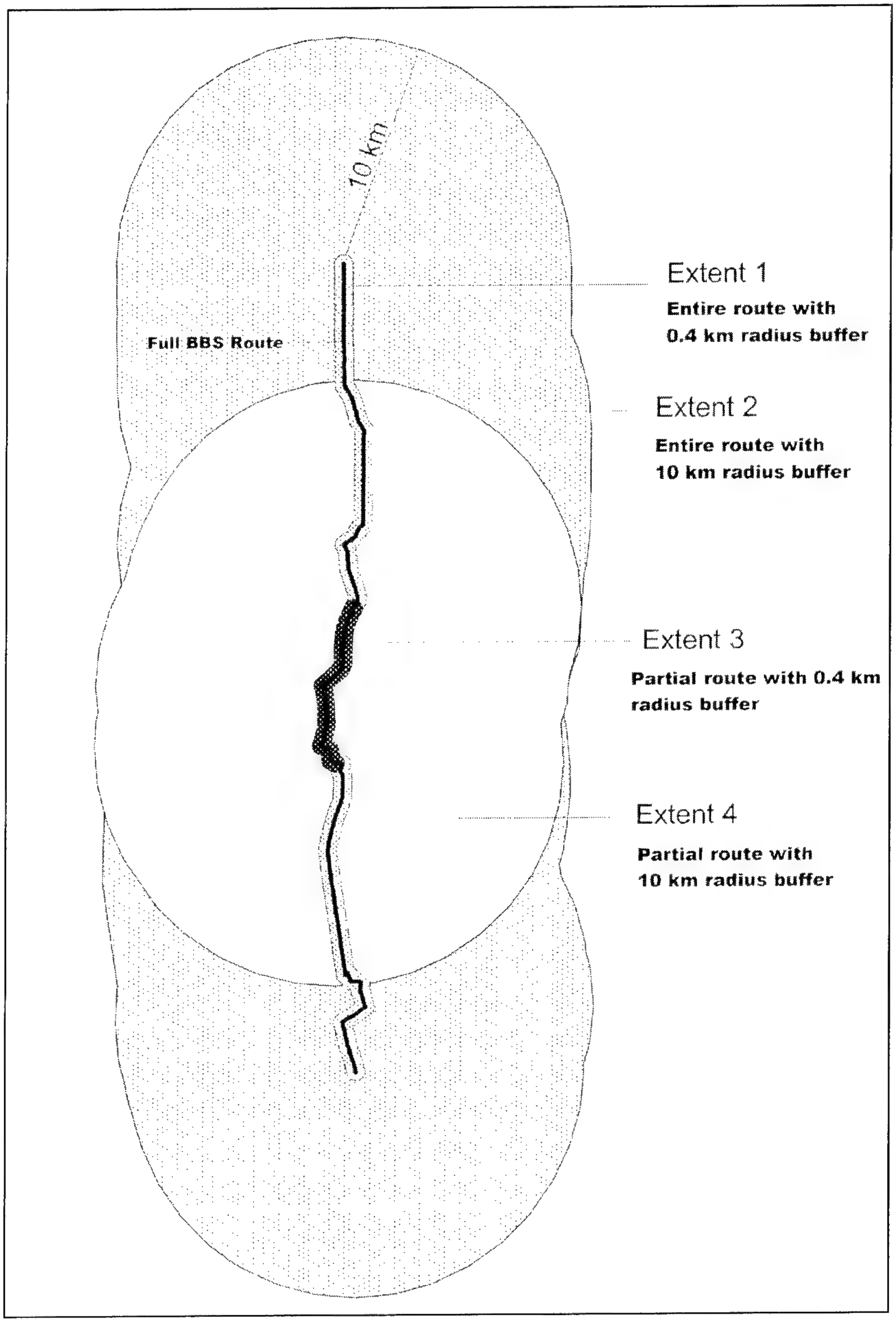


Figure 7. Diagram of a BBS route and the 4 physical study area extents formed by buffering the entire and partial routes with a 0.4 km and 10 km radius buffer.

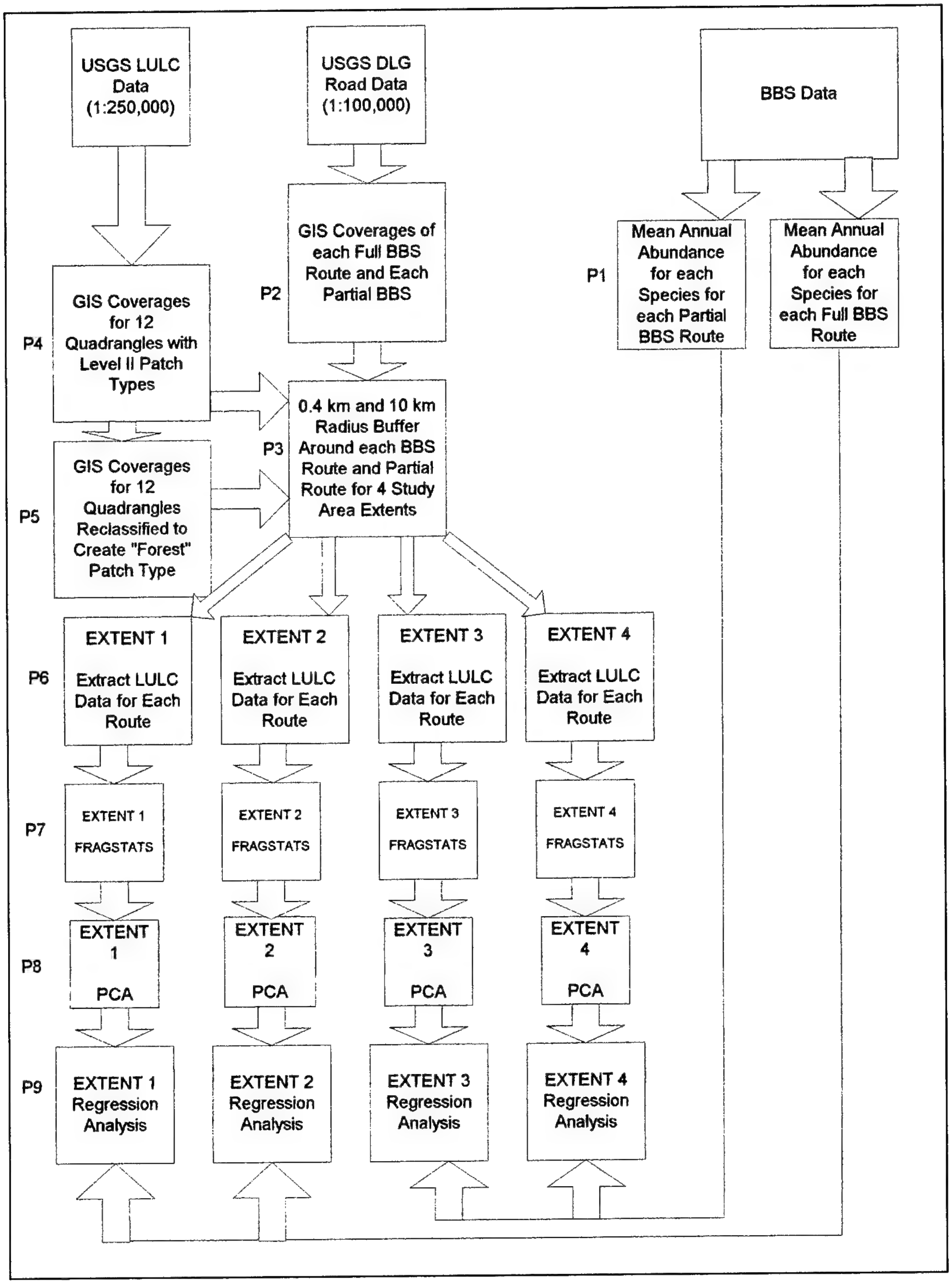


Figure 8. Schematic outline of sequence of procedures used to assess bird and landscape structure associations.

Table 4. Landscape spatial pattern metrics used in this study.

Metric Nomenclature	Type of Metric	Range in Value	Calculation	Patch Type Calculation Based On:
Percent Agriculture (% Ag)	Composition (area)	0 < %Ag <= 100	Sum of the areas of all patches of the corresponding patch type, divided by total landscape area, multiplied by 100	Cropland and pasture
Percent Deciduous Forest (% Dec)	Composition (area)	0 < %Dec <= 100	Sum of the areas of all patches of the corresponding patch type, divided by total landscape area, multiplied by 100	Deciduous forest
Percent Evergreen Forest (% Ev)	Composition (area)	0 < %Ev <= 100	Sum of the areas of all patches of the corresponding patch type, divided by total landscape area, multiplied by 100	Evergreen forest
Percent Mixed Forest (% Mx)	Composition (area)	0 < %Mx <= 100	Sum of the areas of all patches of the corresponding patch type, divided by total landscape area, multiplied by 100	Mixed forest
Percent Forested Wetland (% Fw)	Composition (area)	0 < %Fw <= 100	Sum of the areas of all patches of the corresponding patch type, divided by total landscape area, multiplied by 100	Forested wetland
Mean Patch Size (MPS)	Configuration (size)	MPS > 0, without limit. Range limited by the minimum patch size and extent of image	Sum of the areas of all patches of the corresponding patch type, divided by the number of patches of the same type	Forest
Patch Density (PD)	Configuration (density)	PD > 0, without limit	Number of patches of the corresponding patch type divided by total landscape area	Forest
Edge Density (ED)	Configuration (edge)	ED >= 0, without limit	Sum of the lengths of all edge segments involving corresponding patch type, divided by the total landscape area	Forest
Mean Shape Index (MSI)	Configuration (shape)	MSI >= 1, without limit. MSI = 1 when all patches of the corresponding patch type are circular MSI increases without limit as the patch shapes become more irregular	Sum of the patch perimeter divided by the square root of patch area for each patch of the corresponding patch type, adjusted by a constant to adjust for a circular standard, divided by the number of patches of the same type	Forest
Total Core Area Index (TCAI)	Configuration composition (core area)	0 <= TCAI < 100 TCAI = 0 when none of the patches of the corresponding patch type contain any core area TCAI approaches 100 when the patches of the corresponding patch type, because of size, shape, and edge width, contain mostly core area	TCAI equals the percentage of a patch type in the landscape that is core area based on a 250 m (Robinson et al. 1995, Temple 1986) specified edge width	Forest
Simpson's Diversity Index (SIDI)	Composition (diversity)	0 <= SIDI < 1 SIDI = 0 when the landscape contains only 1 patch SIDI approaches 1 as the number of different patch types (patch richness) increases and the proportional distribution of area among patch types becomes more equitable Higher value the greater likelihood only two randomly drawn patches would be different patch types (greater diversity)	SIDI equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared	All level II patch types simultaneously
Interspersion and Juxtaposition Index (IJI)	Configuration (interspersion)	0 < IJI <+ 100 Approaches 0 when distribution of adjacencies among unique patch types becomes increasingly uneven. Equals 100 when all patch types are equally adjacent to all other patch types.	IJI equals the observed interspersion over the maximum possible interspersion for the given number of patch types	All level II patch types simultaneously

Table 5. Years of BBS data used for each BBS route (from 1970-1976) to develop the mean yearly abundance for each species. An "x" signifies that the BBS data were available for that year.

STATE	ROUTE NUMBER	1970	1971	1972	1973	1974	1975	1976
AL	1		x	x	x	x	x	
AL	2		x	x	x	x	x	
AL	4		x		x		x	
AL	5		x	x	x	x	x	
AL	6		x	x	x	x	x	
AL	7		x	x	x	x		
AL	8		x	x	x	x	x	
AL	9		x	x	x	x	x	
AL	10		x	x	x			
AL	11		x	x	x	x		
AL	12		x	x	x	x	x	
AL	13		x	x	x	x	x	
AL	15		x	x	x	x	x	
AL	16		x	x	x	x	x	
AL	17		x	x	x	x	x	
AL	22		x	x	x	x	x	
AL	23		x	x	x	x	x	
AL	24		x	x	x	x	x	
AL	25		x	x	x			
AL	26		x	x	x	x	x	
AL	28		x	x	x	x	x	
AL	29		x	x	x	x	x	
AL	30		x	x	x	x	x	
AL	31			x	x	x	x	
AL	32		x		x	x	x	
AL	34		x	x	x	x	x	
AL	35		x		x	x	x	
AL	36		x	x	x	x	x	
AL	37		x	x	x	x	x	
AL	38		x	x			x	
AL	41		x	x	x		x	
AL	43		x	x	x	x	x	
AL	44		x	x	x	x	x	

Table 5. (contin'd) Years of BBS data used for each BBS route (from 1970-1976) to develop the mean yearly abundance for each species. An "x" signifies that the BBS data were available for that year.

STATE	ROUTE NUMBER	1970	1971	1972	1973	1974	1975	1976
GA	6		x	x	x	x	x	
GA	10		x	x	x	x	x	
GA	16				x	x	x	
GA	22				x	x	x	
GA	25			x	x	x	x	
GA	26		x	x	x	x	x	
GA	28				x	x	x	x
GA	33				x	x	x	
GA	36				x	x	x	
GA	37		x	x	x	x	x	
GA	38	x	x	x	x	x	x	
FL	1		x	x	x		x	
FL	2		x	x	x		x	
FL	3		x	x	x		x	
FL	4	x	x	x	x	x		
FL	5	x	x	x	x			
FL	6	x	x	x	x			
FL	7	x	x	x	x		x	
FL	8	x	x	x	x			
FL	9		x	x	x	x	x	

Table 6. Highest mean count/route for 15 bird species. Developed from BBS data from 1966-1985 (Hamel 1992).

Species Name	***AOU No.***	**Highest mean count/route**
Prairie Warbler	6730	66
Northern Bobwhite	2890	277
Field Sparrow	5630	108
Loggerhead Shrike	6220	32
Eastern Kingbird	4440	36
White-eyed Vireo	6310	249
Eastern Wood-pewee	4610	27
Yellow-throated Vireo	6280	16
Hooded Warbler	6840	24
Wood Thrush	7550	53
Yellow-billed Cuckoo	3870	46
Kentucky Warbler	6770	20
Brown-headed Nuthatch	7290	19
Prothonotary Warbler	6370	50
Brown-headed Cowbird	4950	94

Table 7. Patch types in Level I and II of the USGS LULC dataset.

LEVEL I	LEVEL II
Urban or built-up land	Residential
	Commercial and services
	Industrial
	Transportation, communication, utilities
	Industrial and commercial complexes
	Mixed urban or built-up land
	Other urban or built-up land
Agricultural land	Cropland and pasture
	Orchards, groves, vineyards, nurseries and ornamental horticultural areas
	Confined feeding operations
	Other agricultural land
Rangeland	Herbaceous rangeland
	Shrub and brush rangeland
	Mixed rangeland
Forest land	Deciduous forest land
	Evergreen forest land
	Mixed forest land
Water	Streams and canals
	Lakes
	Reservoirs
	Bays and estuaries
Wetland	Forested wetland
	Nonforested wetland
Barren land	Dry salt flats
	Beaches
	Sandy areas not beaches
	Bare exposed rock
	Strip mines, quarries, gravel pits
	Transitional areas

Table 8. Number of study sites in the four extents containing deciduous forest, evergreen forest, mixed forest, or forested wetland.

Patch Type	Number of Study Sites			
	Extent 1	Extent 2	Extent 3	Extent 4
Deciduous forest	24	43	67	183
Evergreen forest	43	53	152	260
Mixed forest	52	53	234	265
Forested wetland	18	40	46	163

CHAPTER IV

RESULTS

Introduction

The analysis encompassed four discrete steps: extracting abundance values for each bird species from each landscape unit (BBS route), dividing landscape metrics into appropriate categories, summarizing landscape metrics into PCA axes to remove autocorrelation, and exploring the sensitivity of bird abundance to the various PCA axes.

Extracting Abundance Values for Each Bird Species from Each Landscape Unit

Each BBS route is approximately 40-km long and consists of 50 stops spaced 0.8 km apart (Keller and Scallan 1999). The records for each BBS route included the number of individuals of each species of bird observed for the first ten stops, second ten stops, third ten stops, fourth ten stops, and fifth ten stops, and for the full BBS route (Robbins et al. 1986). It is these five 10-stop summaries or 5 mile subsegments that form the basis of the 5 partial BBS routes, and together, the full BBS route. There were 53 full BBS routes used in this study. And with each of the 53 full BBS routes broken into 5 partial routes, this resulted in 265 partial BBS routes in the study. Since the partial routes provided a finer level of detail, these data were used as well as the more typical full BBS route data.

The species included in this study were identified as conservation priority species in 1998. The data that were used in this study are based on BBS data from 1970-1976. Even though the species had not yet been listed as conservation priority in the 1970-1976 timeframe, the average of the 53 mean count of birds/route for each species were low, with the exception of the Northern Bobwhite (Figure 9). The more recent timeframe included in Figure 9 (1994-1998), shows that the mean yearly count of birds/route are low, with the Northern Bobwhite decreasing substantially from the 1970-1976 timeframe. Based on the 53 full BBS routes the mean count of birds/route for each species were categorized into accidental, low, medium, and high abundance categories (Hamel 1992). These groupings are based on the same groupings developed by Hamel and used for range maps for birds across the South (Hamel 1992). The groupings are useful in determining the routes that have high or medium abundance and presumably the most suitable habitat. Based on Figure 10, the majority of BBS routes have a low or accidental abundance for 11 of the species under study. The remaining 4 species have a medium to high abundance on the majority of routes.

The relative abundance data from the partial BBS routes was also examined. Since there is no accepted method for categorizing the partial routes into abundance categories, a table is used to show the distribution of each species into groups of mean yearly count of birds/partial route (Table 9). For six of the bird species, there were zero counts for over 50 % of the partial routes. For all bird species studied (except the Northern Bobwhite), well over 50% of the partial routes had zero counts or less than or equal to 1 mean yearly count of birds/partial route. The Northern Bobwhite was the

exception, since it had a much higher mean yearly count of birds/partial route than the other species.

Dividing Landscape Metrics Into Appropriate Categories

The landscape structure was quantified using a suite of 12 spatial metrics calculated from USGS LULC data for each of the four extents around each BBS route. As used in this report, the term "Extent 1" is a 0.4 km radius buffer of a full BBS route; "Extent 2" is a 10 km radius buffer of a full BBS route; "Extent 3" is a 0.4 km radius buffer of each partial BBS route; and "Extent 4" is a 10 km radius buffer of each partial BBS route. The extents are illustrated in Figure 7.

The variation of the metric values for the 4 extents indicates that the extent of the analysis area substantially influences some landscape spatial pattern metric values (Table 10). The narrow width extents resulted in mean patch sizes and core area values that were universally smaller, while also producing patch density values that were substantially larger, and edge density, and interspersion values that were slightly larger. There were less noticeable differences in the MSI and SIDI values. These findings are also illustrated by the distribution of the values of PD, MPS, ED, MSI, TCAI, SIDI, and IJI for all sites for the 4 extents, which are shown in Figures 11-17, respectively. Again, the pattern of difference is particularly evident in the distribution of values for PD, MPS, TCAI between Extents 1 and 3 versus Extents 2 and 4.

The composition metrics were not as affected by spatial extent. Figure 18 shows that the cropland and pasture, deciduous forest, evergreen forest, mixed forest, and

forested wetland patch types used in this study were quite similar in percent for the 4 extents. For all extents, these patch types comprised approximately 90 % of the landscape.

Summarizing Landscape Metrics into PCA Axes to Remove Autocorrelation

A principal components analysis was used to simplify the structure of the spatial metric data sets by reducing them to a smaller set of uncorrelated variables that account for a large part of the variation in the original data set. Principal components analyses performed to describe landscape structure produced similar components for the 4 different extents (Table 11). PCs are interpreted based on the pattern and strength of the loadings. Based on the component loadings, the 3 PCs in the study, were universally interpreted as configuration (PC1), composition (PC2), and diversity/interspersion (PC3). These PCs provided a good summary of all the original variables.

The results for the PC analyses for the 4 extents is listed in table 11. The eigenvalue, percent variance, and cumulative variance for each component for each extent are listed at the top. The eigenvalue provides a means of identifying the number of components retained in each analysis. Principal components with eigenvalues > 1.0 with meaningful interpretations based on the pattern and strength of the loadings were retained. Three components were retained for all extents. The percent variance explains the amount of variance in the dataset explained by each principal component. The cumulative percent variance simply provides a cumulative total of the percent variance explained by two or more PCs. PC1 accounted for about 35-37 percent of the variance in

the landscape datasets for Extents 1-4, while PC1 and PC2 together explained about 50-56 percent of the variance, and all three PCs combined explained about 65-74 percent of the variance in the landscape datasets.

The lower part of Table 11 lists the component loadings. The component loadings are the correlations between the principal component and each original variable. The interpretation of component loadings was based on the largest loadings for each component. Generally, this included all correlations greater than 0.5. These are listed in bold type in the table. The correlations between the principal component and each original variable are either negative or positive. This is depicted in Table 11 with a "-" or "+" sign in front of the loading.

In each case, PC1 had high component loadings for MPS, TCAI, ED, PD, and MSI. These are all measures that help to describe the configuration of a forested landscape. Therefore, PC1 was interpreted as an overall configuration component, contrasting a fewer number of more complex shaped large forest patches with large core areas with a relatively small amount of edge in largely forested landscapes (positive loading), with many small more simplistically shaped patches with small core areas, with a relatively large amount of edge, in mostly agricultural landscapes (negative loading). PC2 had high component loadings for percent mixed forest, evergreen forest, and forested wetlands. These are all measures that describe the habitat composition of a landscape. Therefore, PC2 was interpreted as a composition component, contrasting mostly evergreen or forested wetland landscapes (positive loadings) with mixed forest landscapes (negative loading). That these variables loaded separately on their own

principal component, indicates that the habitat composition varies independently of the configuration of the forest in a landscape. Finally, PC3 had high component loadings for SIDI, IJI, and deciduous forest. These are measures that describe diversity and interspersion of the landscape. Therefore, PC3 was interpreted as a diversity/interspersion component, contrasting diverse and interspersed landscapes (positive loading) with landscapes that are not diverse and interspersed.

Based on the principal components analysis, it was concluded that similar landscape structure components exist for all spatial extents; the configuration of the forest varies independently of the habitat composition; and both the configuration of the forest and the habitat composition vary independently of the diversity and interspersion of the landscape.

Exploring the Sensitivity of Bird Abundance to the Various PCA Axes

How the landscape structure components are associated with the observed abundance of the conservation priority bird species was examined using the results of the PCA. A stepwise multiple regression analysis was conducted in which the 3 principal components were included as new variables to model their associations with the abundance of each bird species. The mean yearly bird count/route or partial route for each of the fifteen bird species and the habitat utilization bird groups was regressed on the calculated PCA scores for the three PCs. This resulted in 60 multiple linear regression models for the individual bird species and 12 for the habitat utilization bird groups. The results of the stepwise multiple regression analyses indicated which

components showed the strongest relationships with relative abundance of bird species. The R^2 values represent the proportion of the variation in relative abundance that can be explained by variation in the components included in the model. Based on the 4 extents, the models explained 3-50% of the variation in abundance of the individual species. The models developed for Extent 1 explained 8-50% of the variation in abundance of the individual species; those developed for Extent 2 explained 14-39%; those developed for Extent 3 explained 4 - 28%; and those developed for Extent 4 explained 3-19%.

A summary of each stepwise multiple regression model is listed in Table 12. The constant and coefficients are not listed in Table 12, rather a "+" or "-" is used. A "+" represents a positive association with the component, while a "-" represents a negative association with the component. The partial R^2 values are listed for each component in the model, as well as the R^2 value for the full model. If there is no data, this means the PC was excluded from the model in the stepwise multiple regression analysis. All variables included in the model have a $P < 0.05$.

In spite of the relatively high degree of unexplained variance, the models generated in this study provide a methodology for determining which kilometer-resolution horizontal spatial pattern metrics provide indicators of habitat suitability for the species under study. These models are not suitable for predicting bird abundance, however; the methods can be used when assessing the relative importance of areas for conservation efforts and in stratifying the areas into categories of suitability for the species to be conserved or assessing the impacts of alternative management plans that could alter or remove habitat for bird species. The following summary of results pertains

to the extent 1 analysis. The overall findings from extent 1 resulted in the best overall results and best illustrate the relationship between bird abundance and kilometer-resolution horizontal spatial pattern metrics.

The forest configuration and habitat composition components (PC1 and PC2) were found to be the most frequent significant predictors of relative abundance for the 15 bird species. The diversity/interspersion component (PC3) was a significant predictor of abundance for only 2 birds. Some general observations can be made about the way that the relative abundance of individual species were predicted by the different components. Specifically, a suite of species that included the White-eyed Vireo, Yellow-throated Vireo, Hooded Warbler, Wood Thrush, Kentucky Warbler, Brown-headed Nuthatch, and the Prothonotary Warbler were positively associated with the configuration component. This appears to support the categorization of these birds as forest interior to forest interior/edge species, i.e. preferring relatively fewer patches with less edge, that have a relatively large forest core area and mean forest patch size. Another set of species, the Prairie Warbler, Northern Bobwhite, Field Sparrow, Loggerhead Shrike, and the Eastern Kingbird, appear to be edge species. These birds responded negatively to the configuration component, inferring they prefer edge dominated sites with many patches that have a smaller mean patch size and core area. Not surprisingly, the Brown-headed Cowbird appears to be a generalist in that it was not affected by forest configuration, and did not seem to prefer forest interior or edge type habitats. The Yellow-Billed Cuckoo was also not sensitive to habitat configuration, a finding that is consistent with previous landscape scale research (Howell et al. 2000). In general, with species grouped by

habitat utilization, those species grouped as interior species or interior/edge species responded positively to the configuration component, while those species grouped as edge and scrub plus field-edge species appear to be respond negatively to the configuration component.

A suite of species, including the Wood Thrush, Kentucky Warbler, Eastern Wood-Pewee, Prairie Warbler, Brown-headed Cowbird, Yellow-billed Cuckoo, and the Field Sparrow appear to be negatively associated with the habitat composition component. This implies that these species prefer areas with relatively large amounts of mixed forest and small amounts of evergreen forest or forested wetland. The Prothonotary Warbler was the only species that responded positively to the habitat composition component, preferring areas with relatively large amount of forested wetland or evergreen forest and small amount of mixed forest. This information is consistent with that developed at the patch level, except for the Field Sparrow and Prairie Warbler (Hamel 1992). On the basis of the results of this analysis, the individual species were lumped together into habitat utilization groups for another stepwise multiple regression analysis.

Habitat Utilization Groups

The interior bird species had an R^2 value of 38 % for Extent 1. They were positively associated with forest configuration and negatively associated with habitat composition, with forest configuration explaining about 28% of the variance and habitat composition explaining about 10% of the variance. The model for the interior bird

species indicated that the birds were more likely to be found in mixed forest landscapes, with large forest patches and forest core areas, and a fewer number of patches with more complex shapes and edge.

The interior/edge bird species had an R^2 value of 42% for Extent 1. They had the same associations with the landscape as the Interior bird species, that is they were positively associated with the forest configuration component and negatively associated with the habitat composition component. Forest configuration explained about 20% of the variance and habitat composition explained about 16% of the variance. The model for the interior/edge species indicated that the birds were more likely to be found in mixed forest landscapes, with large forest patches and forest core areas, and a fewer number of patches with more complex shapes and edge.

The edge and scrub, field-edge bird species had an R^2 value of 36% for Extent 1. They had a negative association with the forest configuration component and a negative association with the habitat composition component. Forest configuration explained about 26% of the variance and habitat composition explained about 10% of the variance. The model for the edge and scrub, field-edge species indicated that the birds were more likely to be found in mixed forest landscapes, with a larger number of smaller forest patches and forest core areas that have more simplistic shapes and more edge.

Individual Species with Highest R^2 Values

Out of the 15 species studied, five species had models with R^2 values from 37-50% (Table 12 and 13). This still leaves a great amount of unexplained variance.

However, given that existing datasets were used and the other limitations of the current study, these findings show promise for further investigation. The five species with the highest R^2 values were the Wood Thrush, Hooded Warbler, White Eyed Vireo, Kentucky Warbler, and Prothonotary Warbler. The 10 remaining species had lower, highly variable R^2 values. For these 10 cases, the large amount of unexplained variance limits a meaningful discussion of the models for those particular species. Further examination of the other 5 species with relatively higher R^2 values is informative. The form of the model is shown below as Equation 9. Table 13 lists the coefficients for the statistical models for each of these species. The habitat suitability needs for these bird species were also assessed using logistic regression.

$$Abundance = C_0 + C_1(PC1) + C_2(PC2) + C_3(PC3) \tag{9}$$

The statistical models for the individual species are best understood from the perspective of each species' natural history and habitat preferences.

Wood Thrush

The model for the Wood Thrush had an $R^2 = 50\%$. In the multiple regression analysis in this study, the Wood Thrush responded primarily to habitat composition ($pR^2 = 44\%$) and to a much lesser degree forest configuration ($pR^2 = 6\%$). In the logistic regression analysis, the Wood Thrush responded significantly only to the habitat composition of the landscape. As the habitat increased in mixed forest and decreased in evergreen and forested wetlands, the probability of medium to high Wood Thrush

abundance increased (Figure 19). It appears, from this study, that the Wood Thrush may not be affected so much by the core area and size of the forest patches, assuming that the forest fragments are large enough to include an average territory size. These landscape level findings are consistent with previous research conducted at the patch level. In previous research it was found that forest area was a significant predictor of relative abundance for the Wood Thrush, with the predicted probability of occurrence increasing as the area of forest increased (Robbins et al. 1989). The Wood Thrush is a ground-foraging Neotropical migrant that, based on studies at the patch level, prefers interior and edges of deciduous and mixed forest, especially well-developed, upland, mesic ones (James et al. 1984). In contrast, in a recent study in which both vegetation variables and landscape variables were used, the Wood Thrush responded only to multiple vegetation variables (positive association with stems less than 2 cm, logs, and stems greater than 50 cm), suggesting a requirement for second growth forest or a developed understory within a mature forest setting. It did not respond to the landscape variables (MPS, TCAI, ED, %Forest) (Howell et al. 2000). This apparent disparity could be related to the 10-kilometer radius extent on which Howell calculated the landscape metrics. Since the home range for the Wood Thrush is documented as .15 kilometers (Roth et al. 1996), the 10 kilometer extent appears to be excessive. In this dissertation research, the best findings for the Wood Thrush were based on extent 1 (.4 km radius buffer on the entire BBS route). In Robbins et al. (1989), the extent on which the landscape variables were calculated was a 2 km radius buffer. It appears in Howell et al. (2000), that the vegetation variables, which were calculated on a 5 meter radius, are more

important in explaining the abundance of the bird when the landscape variables were calculated on an excessive extent. This does not preclude the association between the bird abundance and landscape variables.

Hooded Warbler

The model for the Hooded Warbler had an R^2 of 45%. In this study, the Hooded Warbler responded positively, at a landscape level, primarily to forest configuration. Forest configuration explained about 35% of the variance and diversity/interspersion explained about 10% of the variance. In the logistic regression analysis, the Hooded Warbler was significantly affected by the forest configuration and diversity/interspersion components. The probability of finding medium to high abundance of the Hooded Warbler increased with increasing forest patch size and core area size and decreasing patch numbers and edge(Figure 20), and increased with lower landscape diversity and interspersion and percent deciduous forest(Figure 21). These landscape level findings are consistent with the existing patch level knowledge about the species. For example, the Hooded Warbler is a small migratory songbird that, in its breeding range, inhabits deciduous and mixed hardwood forests. It favors moist forests with a fairly dense understory (Ogden and Stutchbury 1994). It is considered a forest-interior species because it is restricted to larger woodlots (Hamel 1992). There is one conflict with existing patch level knowledge, in that the Hooded Warbler is known, from a patch habitat scale, to prefer deciduous forest, but as a part of the diversity/interspersion component, the bird is shown not to prefer deciduous forest. Since the

diversity/interspersion component is confounded with the percent deciduous forest variables, it is difficult to determine if the association with this component is based primarily on the diversity and interspersion of the landscape or the percent of the landscape composed of deciduous forest. Nevertheless, by far the most important landscape variable to the Hooded Warbler is the overall configuration of the forest, not the landscape diversity and interspersion.

White-Eyed Vireo

The White-Eyed Vireo model had an R^2 of 41%. In this study, the White-Eyed Vireo responded, at a landscape level, about equally to forest configuration and landscape diversity and interspersion. Forest configuration explained about 20 % of the variance and diversity/interspersion explained about 21% of the variance. In the logistic regression analysis, the White-Eyed-Vireo was significantly affected by forest configuration and diversity/interspersion components. The probability of finding medium to high abundance of the White-Eyed-Vireo increased with increasing forest patch size and core area size and decreasing number of patches and edge (Figure 20), and increased with lower landscape diversity and interspersion (Figure 21). It is surprising that there was a statistically significant positive relationship with the forest configuration component, since the bird is not considered, at a patch level, to be a forest interior bird. In its breeding range, it is common in its preferred habitat of dense secondary deciduous scrub, streamside thickets, wood margins, and overgrown pastures (Hamel 1992, Graber et al. 1985). It would be expected that the bird would have had a negative relationship

with the forest configuration component. The White-Eyed Vireo was only one of two birds that had an association with the diversity and interspersion of the landscape.

There are several possible explanations for the apparently contradictory findings for the White-Eyed Vireo. The most obvious problem is that the USGS LULC dataset lacks a habitat category that coincides with that which the bird has been found to prefer at the local scale. The bird prefers a habitat of secondary deciduous scrub, overgrown pastures and abandoned farmland, or wood margins, and these categories are not depicted on the USGS LULC dataset. Therefore, it is not surprising that the results are inconsistent with existing local habitat knowledge. Also, since the home range of this bird is not known, the extent to which the landscape metrics were calculated could be either too small or too large. Lastly, since the BBS is a roadside survey that has several potential sources of bias, the bird counts for this bird could also be contributing to the apparently contradictory results.

Prothonotary Warbler

The Prothonotary Warbler model had an R^2 of 37%. From a landscape context, the Prothonotary Warbler was most associated with the habitat composition component, and to a lesser degree the forest configuration component. Habitat composition explained about 24% of the variance with forest configuration explaining about 13% of the variance. In the logistic regression analysis, the Prothonotary Warbler was significantly affected by habitat composition and forest configuration. The probability of finding medium to high abundance of the Prothonotary Warbler increased significantly with

decreasing mixed forest cover and increasing evergreen and forested wetland cover (Figure 19), and increased with increasing forest patch size and core area size and decreasing patch numbers and edge (Figure 20). These landscape level findings are consistent with findings at the patch level, in that in breeding areas, it inhabits bottomland hardwood forests and other forested wetlands. It exhibits area sensitivity, avoiding forests < 100 ha in area (Kahl et al. 1985). Other key features of its breeding habitat are presence of water near wooded areas with suitable cavity nest sites, low elevation, flat terrain, shaded forest habitats with sparse understory, and in some places, presence of bald cypress, all of which were not included in this study (Kahl et al. 1985, Petit 1999, Robbins et al. 1989).

Kentucky Warbler

The model for the Kentucky Warbler had an R^2 of 38%. In this study, the Kentucky Warbler responded, at a landscape level, primarily to habitat composition and to a much lesser degree forest configuration. The habitat composition component explained the greater part of the variance at 31%, with forest configuration explaining about 7%. In the logistic regression analysis, the Kentucky Warbler was significantly affected only by forest composition. The probability of finding medium to high abundance of the Kentucky Warbler increased significantly with increasing mixed forest cover and decreasing evergreen and forested wetland cover (Figure 19). In previous research conducted at the patch level, forest area was a significant predictor of probability of occurrence of the Kentucky Warbler (Robbins et al. 1989). It is commonly found in

rich, moist, deciduous forests in the southeastern United States and is rarely observed in agricultural habitats (McDonald 1998) or in conifers (Hamel 1992). Also, a study in Missouri indicated that large blocks of suitable habitat (> 500 ha) are necessary for successful breeding (Gibbs and Faaborg 1990) while the minimum tract size has also been listed as 45 ha (Hamel 1992). Although the species may have minimum are requirements, it does not necessarily have to be present in 1 contiguous patch.

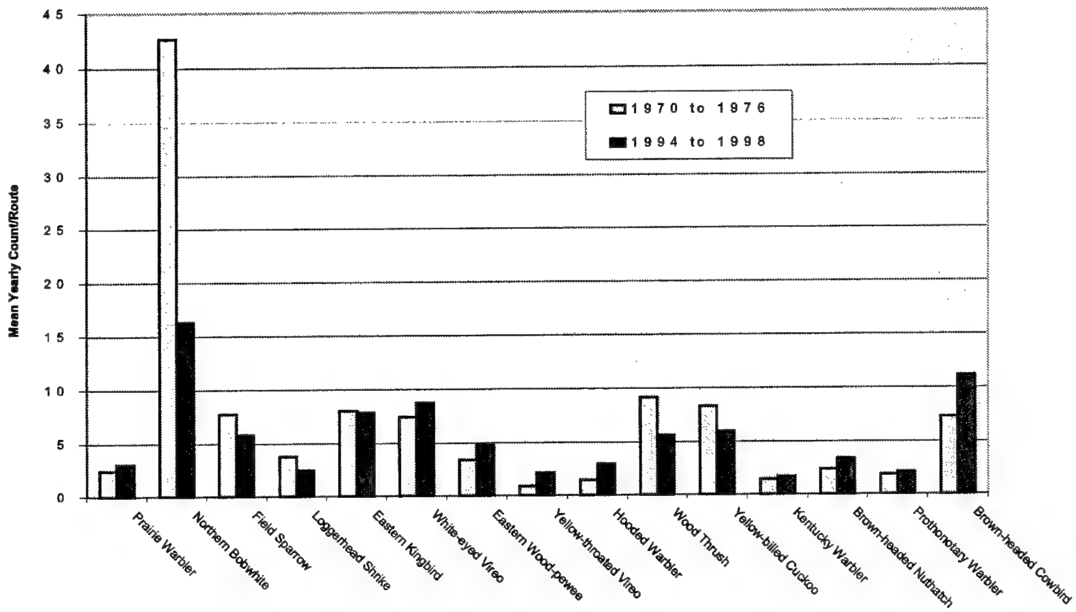


Figure 9. Mean yearly abundance of each bird species across all routes.

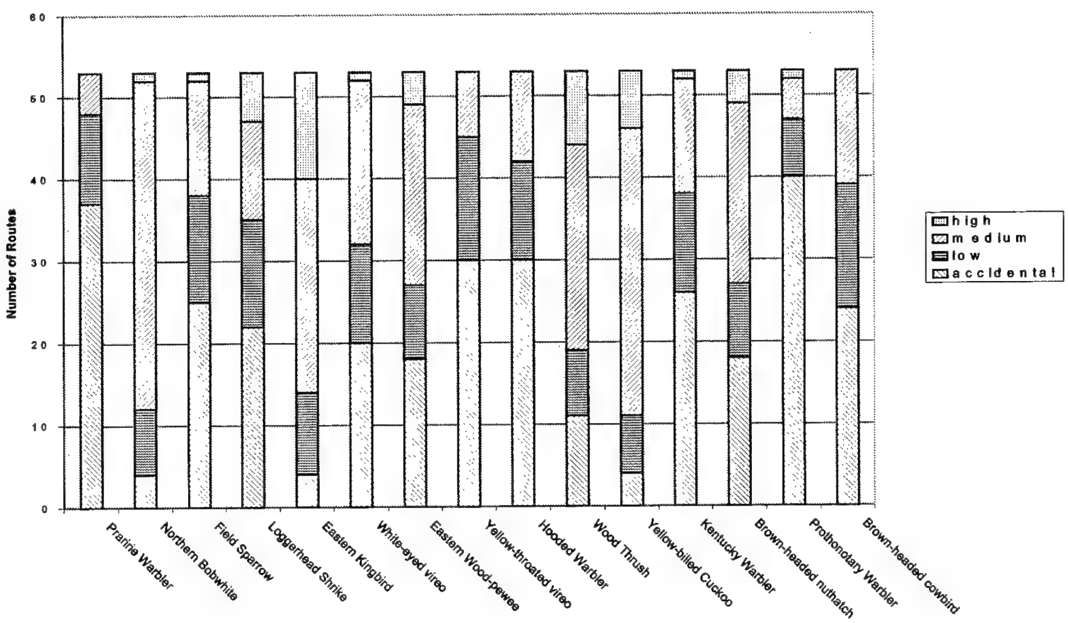


Figure 10. Distribution of birds in terms of high, medium, low, and accidental abundance. Abundance categories determined by first determining the highest mean count/route for each bird species across its range (Table 6) (Hamel 1992).Routes with at least 30 % of the peak value are considered high, 10% are considered medium, 5% of peak value are considered low, and less than 5% are considered accidental abundance (Hamel 1992).

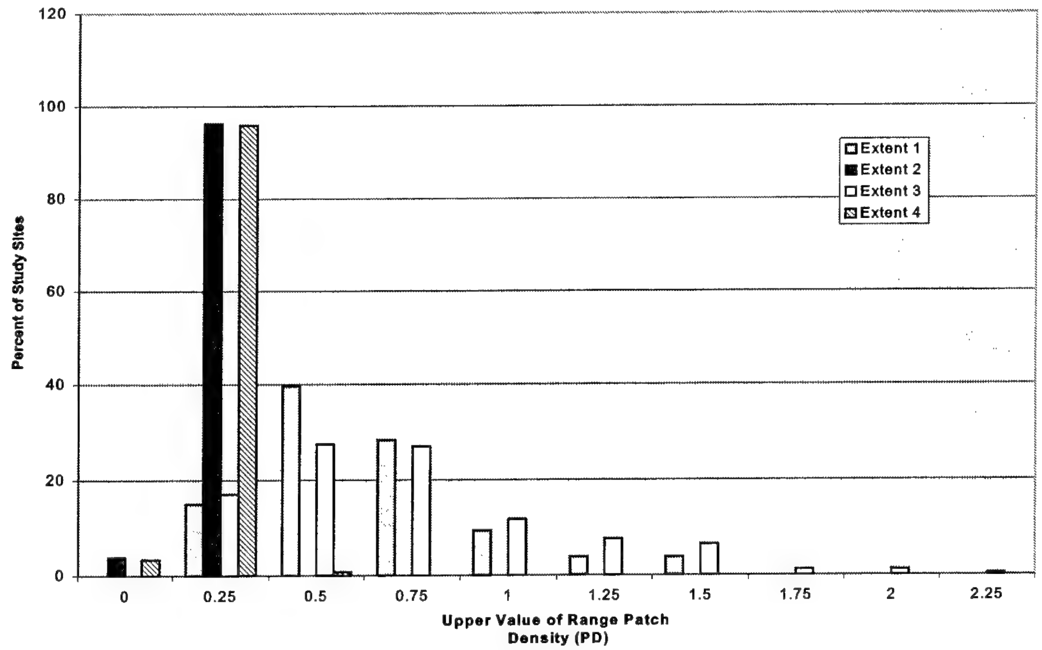


Figure 11. Distribution of the value for patch density for each study site for Extents 1-4.

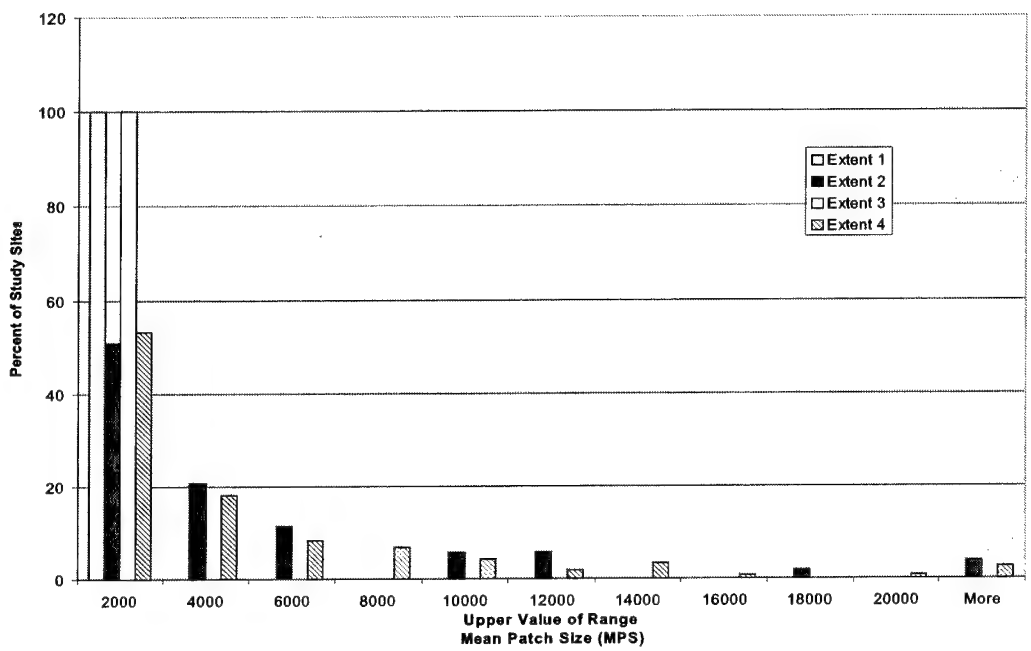


Figure 12. Distribution of the value for mean patch size for each study site for Extents 1-4.

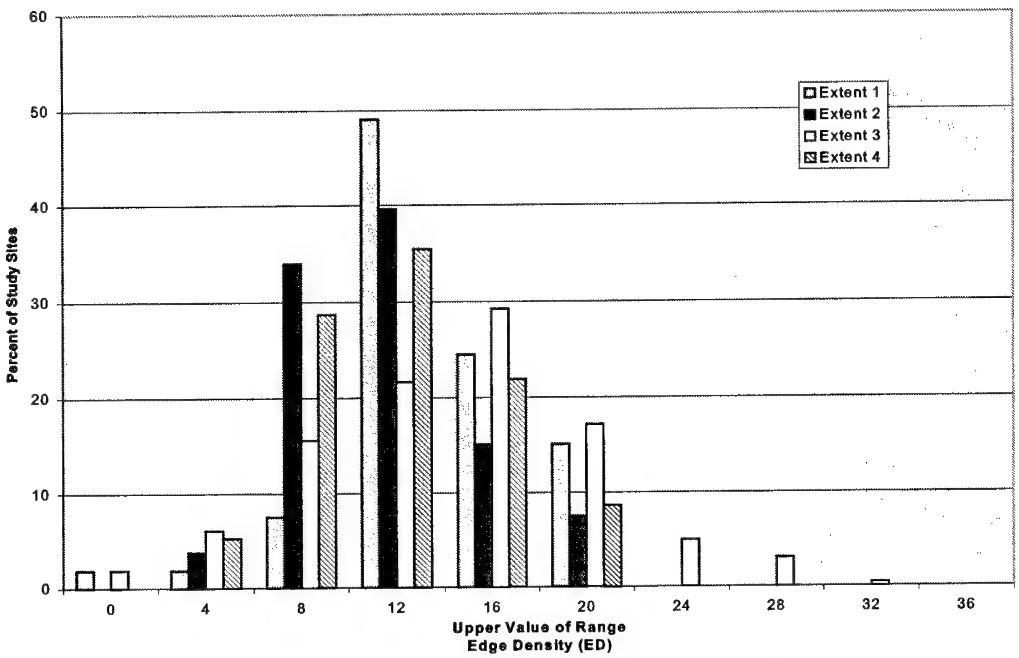


Figure 13. Distribution of the value for edge density for each study site for Extents 1-4.

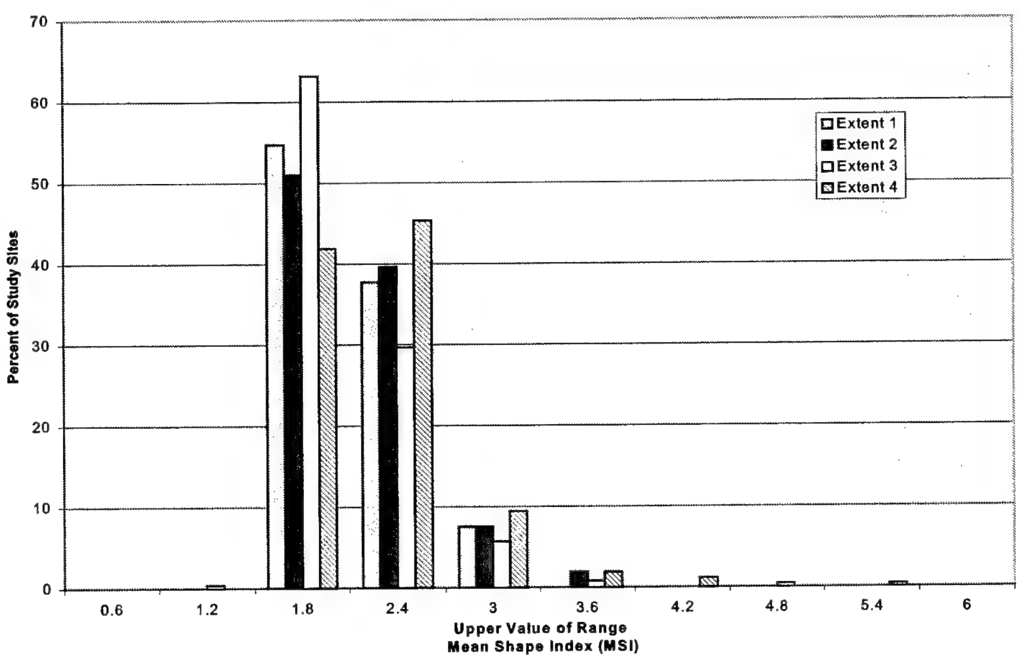


Figure 14. Distribution of the value for mean shape index for each study site for Extents 1-4.

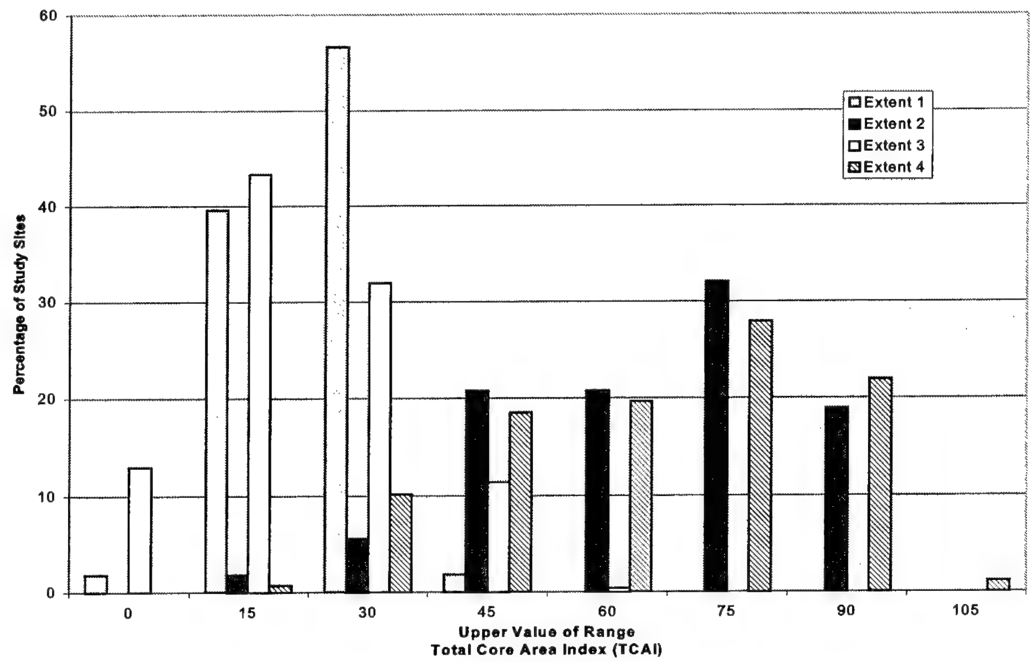


Figure 15. Distribution of the value for total core area index for each study site for Extents 1-4.

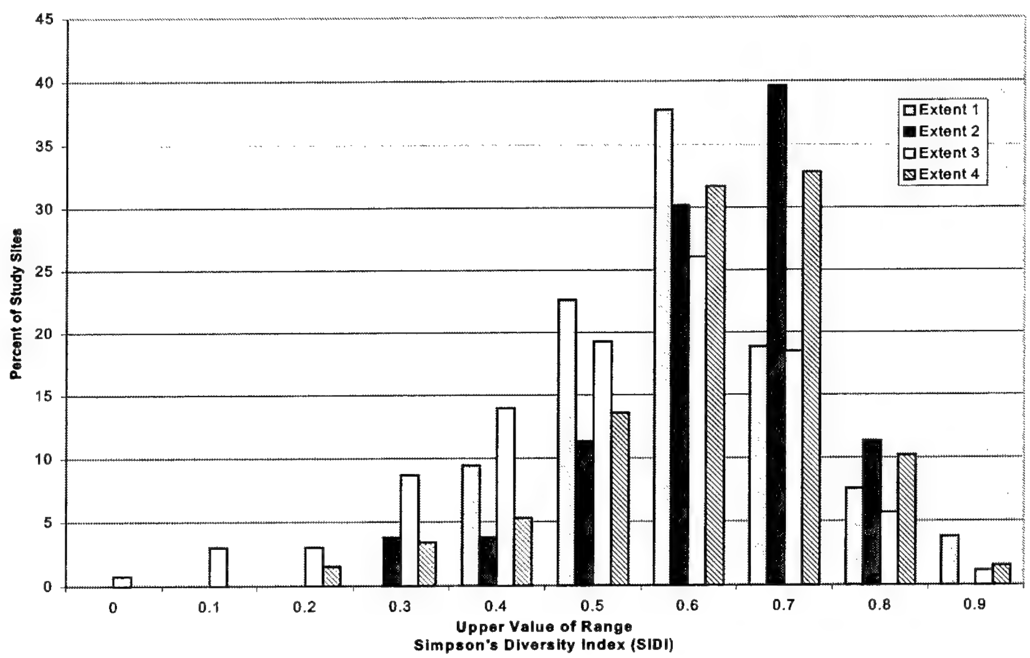


Figure 16. Distribution of the value for Simpson's diversity index for each study site for Extents 1-4.

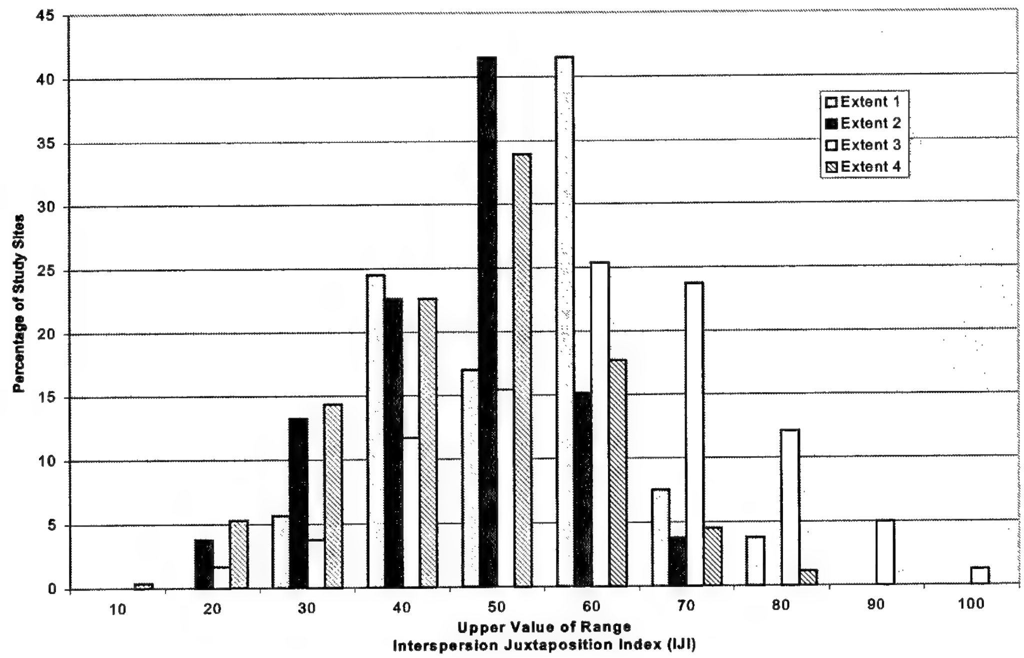


Figure 17. Distribution of the value for interspersion juxtaposition index for each study site for Extents 1-4.

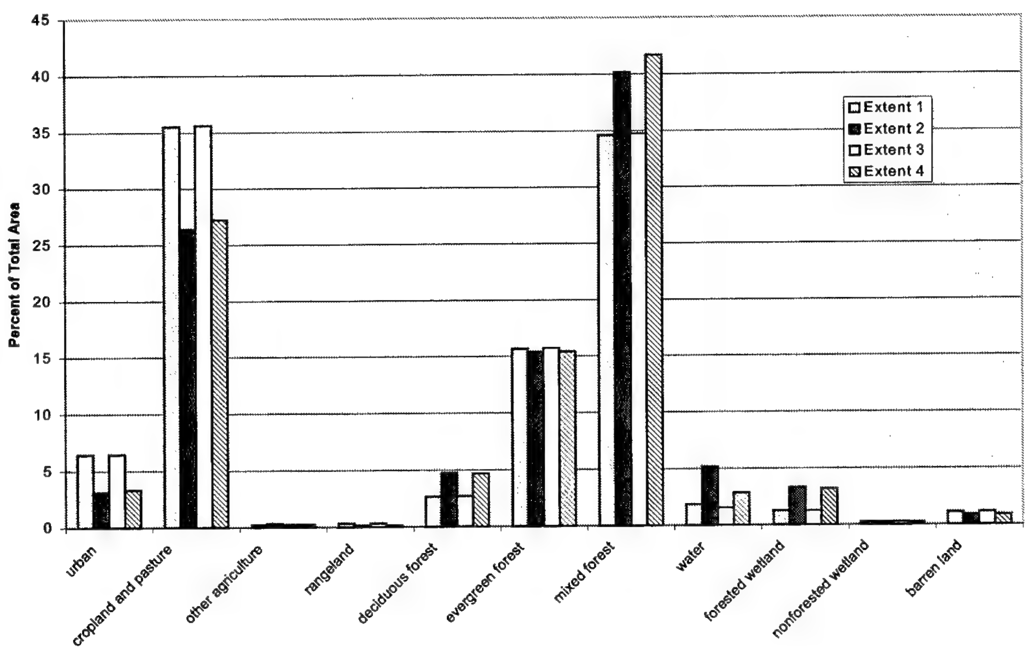


Figure 18. Percent of the total landscape represented by each patch type in Extents 1-4.

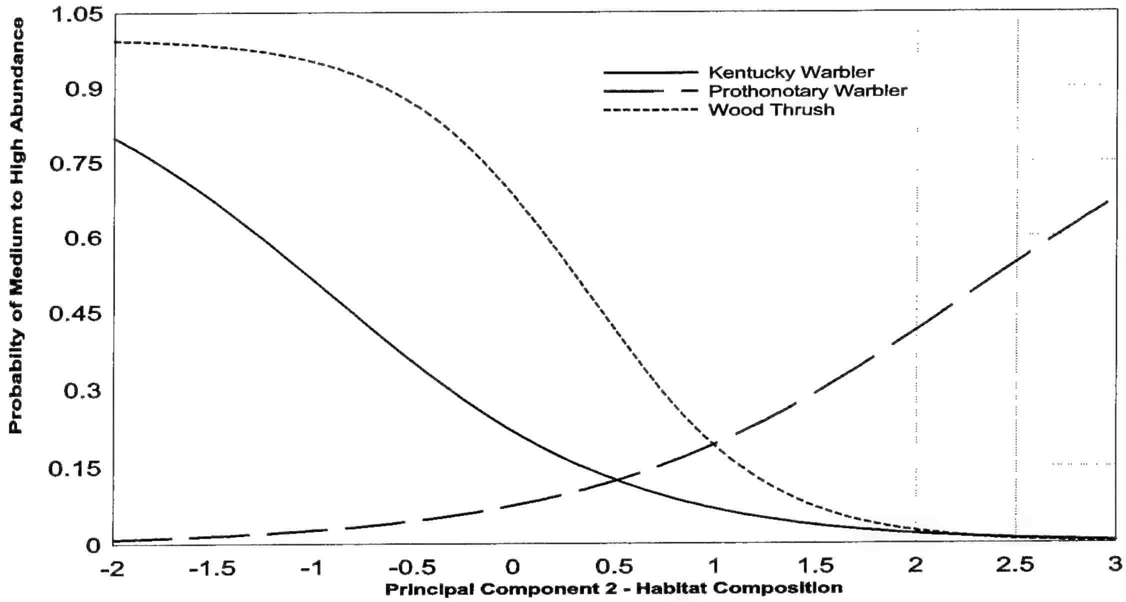


Figure 19. Probability of medium to high abundance, based on logistic regression, for the Kentucky Warbler, Prothonotary Warbler, and Wood Thrush, in relation to habitat composition (PC2).

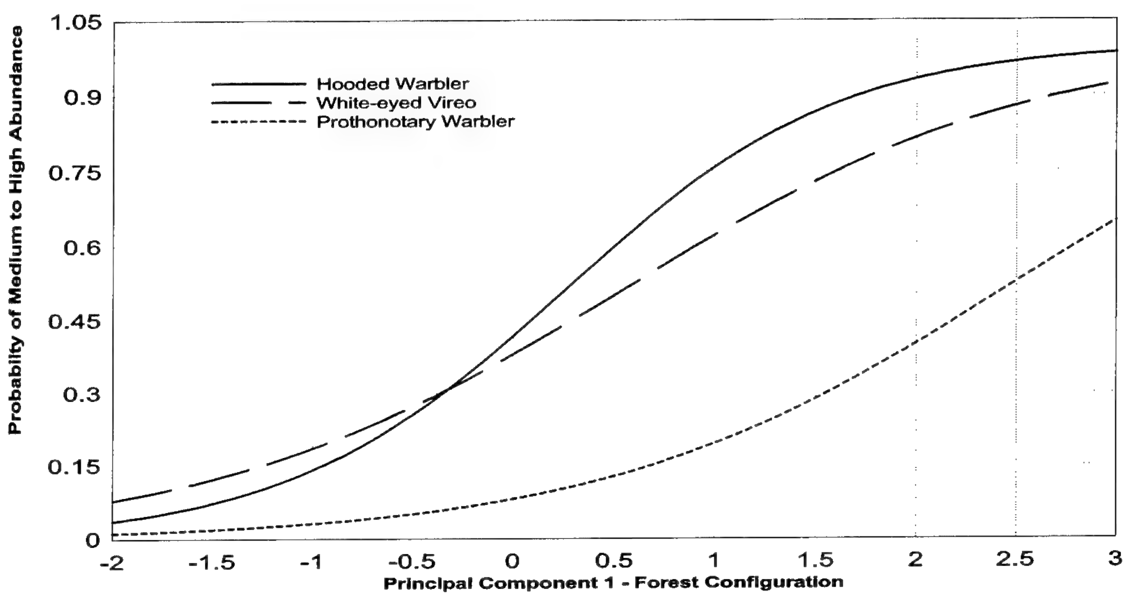


Figure 20. Probability of medium to high abundance, based on logistic regression, for the Hooded Warbler, White-eyed Vireo, and Prothonotary Warbler, in relation to forest configuration (PC1).

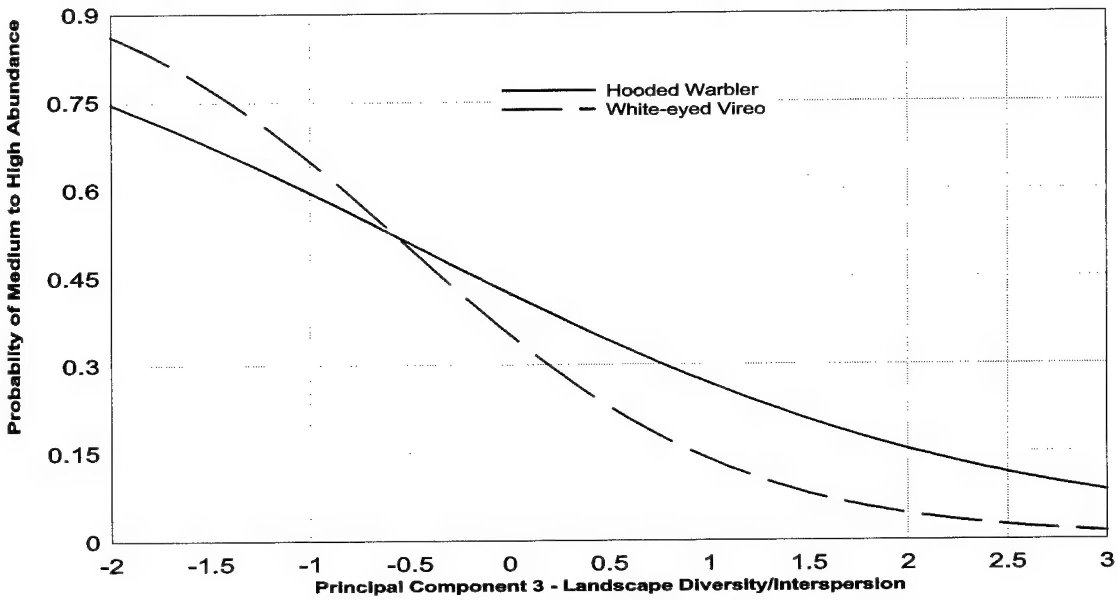


Figure 21. Probability of medium to high abundance, based on logistic regression, for the Hooded Warbler and White-eyed Vireo, in relation to landscape diversity/interspersion (PC3).

Table 9. Frequency of the mean yearly count of birds/route for each species over all partial BBS routes.

Species	*AOU*	*Number of Partial Routes with Mean Yearly Bird Count (S)*											
Name	*Number*	S=0	0<S<=1	1<S<=2	2<S<=3	3<S<=4	4<S<=5	5<S<=6	6<S<=7	7<S<=8	8<S<=9	9<S<=10	10 <S
Prairie Warbler	6730	143	82	24	8	4	3	1					
Northern Bobwhite	2890	3	13	9	13	17	15	17	21	22	19	20	96
Field Sparrow	5630	88	64	35	33	15	10	7	8	2		2	1
Loggerhead Shrike	6220	96	112	29	16	4	3	3		2			
Eastern Kingbird	4440	29	106	54	30	19	20	5	1	1			
White-eyed Vireo	6310	38	107	51	33	13	10	7	3	2		1	
Eastern Wood-pewee	4610	88	124	30	16	6	1						
Yellow-throated Vireo	6280	179	80	6									
Hooded Warbler	6840	151	98	14	2								
Wood Thrush	7550	45	79	54	36	16	16	10	4	1	1	1	2
Yellow-billed Cuckoo	3870	21	85	78	50	17	8	6					
Kentucky Warbler	6770	154	90	19	2								
Brown-headed Nuthatch	7290	123	103	24	9	4	2						
Prothonotary Warbler	6370	165	70	21	4	1	2	1		1			
Brown-headed Cowbird	4950	50	96	50	38	12	10	3	4		2		

Table 10. Summary of the minimum, maximum, mean, and range in value for each metric for each extent.

Metrics	Range	Range	Range	Range	Mean	Mean	Mean	Mean	Min	Min	Min	Min	Max	Max	Max	Max
	Extent 1	Extent 2	Extent 3	Extent 4	Extent 1	Extent 2	Extent 3	Extent 4	Extent 1	Extent 2	Extent 3	Extent 4	Extent 1	Extent 2	Extent 3	Extent 4
Patch Density	1.36	0.19	1.88	0.28	0.53	0.05	0.63	0.05	0.09	0.00	0.14	0.00	1.45	0.19	2.02	0.28
Mean Patch Size	828.80	30429.	682.46	42684.	171.07	4006.0	178.37	3948.1	12.72	81.45	2.16	106.10	841.52	30511.	684.62	42790.
Edge Density	19.61	13.53	28.48	17.57	11.93	9.59	12.26	9.95	0.00	3.17	0.00	1.79	19.61	16.70	28.48	19.36
Mean Shape Index	1.59	1.91	3.21	3.83	1.85	1.89	1.78	1.97	1.40	1.35	1.13	1.39	2.99	3.26	4.34	5.22
Total Core Area Index	36.65	75.05	46.09	77.77	16.59	58.31	14.00	57.37	0.00	12.99	0.00	13.61	36.65	88.04	46.09	91.38
Simpson's Diversity Index	0.55	0.52	0.84	0.69	0.56	0.58	0.48	0.57	0.31	0.23	0.00	0.17	0.86	0.75	0.84	0.86
Interspersion/ Juxtaposition Index	49.22	55.64	83.62	64.48	48.42	40.80	55.81	41.24	26.46	13.43	13.57	9.37	75.68	69.07	97.19	73.85
% Agriculture	80.59	63.92	95.72	77.56	35.36	26.25	35.31	26.55	0.00	0.02	0.00	0.00	80.59	63.94	95.72	77.56
% Forested Wetland	9.15	22.46	18.51	28.28	1.28	3.29	1.27	3.38	0.00	0.00	0.00	0.00	9.15	22.46	18.51	28.28
% Deciduous	20.56	39.45	46.37	65.27	2.71	4.83	2.75	4.60	0.00	0.00	0.00	0.00	20.56	39.45	46.37	65.27
% Evergreen	74.86	73.45	96.18	77.36	15.65	15.29	15.74	15.93	0.00	0.22	0.00	0.00	74.86	73.67	96.18	77.36
% Mixed Forest	81.83	86.28	100.00	91.05	34.85	40.50	34.84	40.65	0.00	1.01	0.00	0.01	81.83	87.29	100.00	91.06

Table 11. Results of the principal components analyses for the 4 extents. Correlations greater than 0.5 are listed in bold type.

	Extent 1 (n=53)			Extent 2 (n=53)			Extent 3 (n=238)			Extent 4 (n=265)		
Rotated Component Matrix	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
Eigenvalue	4.597	2.459	1.544	4.601	2.618	1.631	4.19	1.902	1.621	4.481	2.564	1.602
% Variance	38.31	20.493	12.86	38.34	21.814	13.59	34.91	15.851	13.5	37.34	21.366	13.35
Cumulative Variance	38.31	58.798	71.66	38.34	60.158	73.75	34.91	50.765	64.27	37.34	58.703	72.05
Component Loadings												
Percent agriculture	**-0.821**	-0.249	-0.130	**-0.925**	-0.121	0.076	**-0.782**	-0.234	-0.164	**-0.901**	-0.142	-0.080
Percent forested wetland	0.119	**0.741**	0.145	0.209	**0.810**	-0.075	0.157	0.129	**0.616**	0.187	**0.796**	-0.053
Percent deciduous	0.011	-0.273	**0.765**	0.042	-0.329	**0.700**	0.090	**0.670**	-0.217	0.044	-0.301	**0.641**
Percent evergreen	0.403	**0.792**	-0.177	0.270	**0.860**	-0.053	0.450	-0.167	**0.751**	0.317	**0.851**	-0.038
Percent mixed forest	0.379	**-0.803**	-0.155	0.257	**-0.791**	-0.415	0.356	-0.038	**-0.806**	0.334	**-0.791**	-0.348
Mean patch size	**0.880**	0.066	-0.153	**0.657**	0.154	**-0.518**	**0.912**	-0.121	0.088	**0.710**	0.074	-0.419
Total core area index	**0.876**	-0.117	-0.050	**0.913**	0.078	-0.022	**0.876**	0.000	-0.113	**0.929**	0.112	0.040
Patch density	**-0.870**	-0.055	-0.179	**-0.903**	0.020	0.095	**-0.840**	-0.081	-0.033	**-0.889**	0.032	0.035
Edge density	**-0.546**	0.052	-0.179	**-0.708**	-0.187	-0.218	**-0.618**	0.107	0.034	**-0.792**	-0.202	-0.171
Mean shape index	**0.862**	0.180	-0.114	**0.636**	-0.013	**-0.606**	**0.621**	0.010	0.157	**0.578**	-0.170	-0.444
Simpson diversity index	-0.057	0.304	**0.729**	-0.221	0.277	**0.791**	-0.289	**0.771**	0.169	-0.282	0.249	**0.784**
Interspersion/juxtaposition	0.301	0.492	**0.716**	0.345	0.221	**0.572**	0.136	**0.786**	0.161	0.257	0.132	**0.705**

Table 12. Summary of multiple linear regression models for each bird species for each extent.

Species Name	*AOU*	Extent 1 (n=53)							Extent 2 (n=53)							Extent 3 (n=238)							Extent 4 (n=265)						
		PC1		*PC2*		*PC3*		***Model***	*PC1*		*PC2*		*PC3*		***Model***	*PC1*		*PC2*		*PC3*		***Model***	*PC1*		*PC2*		*PC3*		***Model***
		b	*p*R^2	*B*	*p*R^2	*B*	*P*R^2	R^2	*B*	*P*R^2	*B*	*P*R^2	*B*	*p*R^2	R^2	*B*	*p*R^2	*b*	*P*R^2	*b*	*P*R^2	R^2	*b*	*p*R^2	*b*	*p*R^2	*b*	*p*R^2	R^2
Prairie Warbler	6730			-	18%			**18%**			-	24%			**24%**	+	5%			-	15%	**20%**	+	3%	-	10%			**13%**
Northern Bobwhite	2890	-	23%					**23%**	-	27%					**27%**	-	16%			-	2%	**18%**	-	15%			-	3%	**18%**
Field Sparrow	5630	-	10%	-	7%			**17%**	-	8%	-	14%	+	7%	**29%**	-	4%			-	5%	**9%**	-	7%	-	9%			**16%**
Loggerhead Shrike	6220	-	24%					**24%**	-	27%					**27%**	-	14%	-	2%			**16%**	-	12%			-	4%	**16%**
Eastern Kingbird	4440	-	8%					**8%**	-	17%					**17%**	-	10%					**10%**	-	9%			-	2%	**11%**
White-eyed Vireo	6310	+	20%			-	21%	**41%**	+	19%			-	6%	**25%**	+	23%	-	5%			**28%**	+	14%			-	3%	**17%**
Eastern Wood-pewee	4610			-	29%			**29%**			-	25%			**25%**	+	4%	+	2%	-	15%	**21%**	+	4%	-	15%			**19%**
Yellow-throated Vireo	6280	+	9%					**9%**								+	6%			-	5%	**11%**	+	6%	-	3%	-	2%	**11%**
Hooded Warbler	6840	+	35%			-	10%	**45%**	+	16%					**16%**	+	22%	-	4%			**26%**	+	11%	+	2%	-	2%	**15%**
Wood Thrush	7550	+	6%	-	44%			**50%**			-	25%			**25%**	+	2%			-	18%	**20%**	+	4%	-	13%			**17%**
Yellow-billed Cuckoo	3870			-	9%			**9%**								+	2%			-	6%	**8%**			-	1%	-	2%	**3%**
Kentucky Warbler	6770	+	7%	-	31%			**38%**			-	25%			**25%**	+	7%			-	16%	**23%**	+	4%	-	12%			**16%**
Brown-headed Nuthatch	7290	+	13%					**13%**								+	4%					**4%**	+	3%					**3%**
Prothonotary Warbler	6370	+	13%	+	24%			**37%**	+	7%	+	27%	-	5%	**39%**	+	5%			+	11%	**16%**	+	3%	+	11%			**14%**
Brown-headed Cowbird	4950			-	13%			**13%**			-	14%			**14%**					-	5%	**5%**			-	7%			**7%**
Interior species		+	28%	-	10%			**38%**	+	12%					**12%**	+	20%	-	1%	-	5%	**26%**	+	10%	-	2%	-	2%	**14%**
Interior/Edge species		+	20%	-	16%	-	6%	**42%**	+	13%			-	6%	**19%**	+	16%			-	8%	**24%**	+	13%	-	3%	-	3%	**19%**
Edge and scrub, field-edge species		-	26%	-	10%			**36%**	-	32%					**32%**	-	19%			-	6%	**25%**	-	18%	-	5%	-	3%	**26%**

Table13. Coefficients for the statistical models for each of the five species with R^2 values greater than 36%.

Species Name	AOU	C_0 (Constant)	C_1 (PC1)	C_2 (PC2)	C_3 (PC3)	Model R^2
White-eyed Vireo	6310	7.46	2.72	0.00	-2.78	41%
Hooded Warbler	6840	1.43	0.99	0.00	-0.52	45%
Wood Thrush	7550	9.16	1.76	-4.27	0.00	50%
Kentucky Warbler	6770	1.43	0.43	-0.88	0.00	38%
Prothonotary Warbler	6370	1.86	1.02	1.42	0.00	37%
Interior species		2.87	1.42	-0.86	0.00	38%
Interior/Edge species		33.46	7.68	-6.75	-4.38	42%
Edge and scrub, field-edge species		71.93	-15.93	-9.93	0.00	36%

CHAPTER V

DISCUSSION

Introduction

The intent of this study was to determine if landscape spatial patterns from broad scale data are useful indicators of habitat suitability for the species under study. Resulting models for five of the bird species correctly classified between one-third and one-half of the land area. The unexplained variance (>50%) of these models probably reflects the limitations of this study and the data sources used. Nevertheless, the statistically significant study findings should make it clear that, in addition to the habitat patch preferences and natural history traits of the birds, managers must consider landscape features in conservation and management activities. Applied over broad areas, the methodology and models can substantially contribute to conservation efforts.

Spatial Pattern Metrics and Habitat Suitability Assessment

This study has challenged the common view that BBS data can only be used for trend analysis. The results of the study show that there are significant benefits to utilizing BBS and USGS LULC data to determine which kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability for conservation birds. The bird-to-landscape habitat associations found in this study are generally consistent with patch level habitat preferences. The models generated have low to moderate R^2 values

and hence may not be appropriate for predicting abundance. However, they are appropriate for assessing broad scale habitat suitability and landscape change as reasons for population declines, especially for the five species with $R^2 > 35\%$ (Wood Thrush, Hooded Warbler, White-Eyed Vireo, Prothonotary Warbler, and Kentucky Warbler). This incorporation of spatial pattern metrics from broad scale data should be quite useful in habitat suitability assessment.

Incorporation of spatial pattern metrics into a habitat suitability assessment is premised upon the generation of appropriate metrics. This research is based on the assertion that including a comprehensive set of landscape metrics is the best way to produce an all-encompassing quantitative description of the landscape. Landscape metrics, such as composition, patch size, edge density, patch shape, and core area, are highly correlated, and yet measure significantly different aspects of the landscape (Forman and Gordon 1986). The individual importance of these variables leads to the theory that a landscape is best described, not by its parts, but as a comprehensive whole. For example, misleading findings may result if one includes only the percent forest cover metric in the analysis of two landscapes with equivalent amounts of forest cover. The two landscapes could differ in all other landscape measures (e.g. patch size, edge density, patch shape, core area) due to the patch arrangement. Without other metrics that would provide this additional information, the use of the percent forest metric could result in misleading findings. This contention is supported by the findings of Rosenberg et al. (1999), that inclusion of only a single variable, such as mean forest patch size, may yield misleading conclusions about how birds may respond to habitat changes. Rosenberg et

al. (1999) and others have also been successful in describing the landscape and finding bird-to-landscape associations with a comprehensive set of metrics (McGarigal and McComb 1995, Osborne 1984, Roberts and Norment 1999). In related research, Mladenoff et al. (1997) was also most successful in using a combination of landscape pattern metrics when differentiating landscape pattern from USGS LULC data. The argument for the utilization of a comprehensive set of metrics is not necessarily weakened by the apparent success of other studies that have focused only on individual metrics or a small subset of metrics with relatively strong results. For example, Kruess and Tscharntke (1994) used only an isolation measure to study the fragmentation of habitats in the agricultural landscape and its effect on the number of parasitized insect species ($R^2 = 69\%$). Others have been similarly successful ($R^2 > 40\%$) using only one or two metrics (Temple 1986, McIntyre 1995, Galli et al. 1976, Robinson 1995, Van Dorp and Opdam 1987). Since these studies have focused on a single metric or a few metrics, it is impossible to say if the results could have been improved with a more comprehensive set of metrics.

Inclusion of a comprehensive set of landscape metrics is complicated by their high degree of correlation. In many instances, the search for a metric or metrics that provide the best results in bird-to-landscape habitat associations has centered around the fact that many of the landscape metrics are highly correlated and should not be used together in multiple regression analyses because of their multicollinearity. However, with the use of PCA, the interrelationships among a large number of variables can be explained in terms of their common underlying, uncorrelated principal components (Hair

et al. 1992). This is a powerful concept that allows the inclusion of the influence of all these important variables in spite of their high degree of correlation. The uncorrelated principal components found in the current study and in Rosenberg et al. (1999) and McGarigal and McComb (1995) imply that the components measure different 'dimensions' in the data (Manly 1990). In the current study, the 'dimensions' included habitat composition, forest configuration, and landscape diversity/interspersion. Had only a single variable been assessed, this comprehensive description of the landscape would be replaced by a narrower and perhaps misleading viewpoint. From the PCA (Table 11), the component loadings or correlations of the components and the original variables show that, in the forest configuration component, the MPS, TCAI, PD, MSI, and percent agriculture variables all have about equal loadings. This shows the relative equal importance of all the metrics in providing an overall description of the landscape. Figure 22, provides an example of how misleading it can be if only individual metrics are used to describe a landscape. Figure 22 shows two landscapes with the same MPS, but with landscape B representing a more fragmented landscape than landscape A. The inclusion of the other forest configuration metrics provides a better overall description of the landscape.

The analysis of spatial pattern metrics led to several generalizations that may be useful in addressing habitat suitability issues at a broad scale. For the five best species models, forest configuration was a significant variable in all 5 models, landscape composition was significant in 3 of the models and diversity/interspersion was significant in only 2 of the models. When composition and configuration were the components in

the species models, composition always explained a greater part of the variance. Typically, diversity/interspersion explained the smallest part of the variance in the models. Clearly, considerable focus should be on composition and configuration when addressing habitat suitability issues.

Some species may require further study to clarify bird-to-landscape associations. For example, the White-Eyed Vireo model showed a preference for landscapes with large forest patches with large core areas, less edge and more naturally shaped patches. This is similar to what forest interior species, such as the Hooded Warbler, were found to prefer. This is contrary to what was expected since the White-Eyed Vireo is widely known to prefer dense secondary deciduous scrub, streamside thickets, wood margins, and overgrown pastures (Hamel 1992, Graber et al. 1985), and forest dominated habitats yet with a large component of scrub/shrub (personal communication Hunter 2000). However, since the preferred habitat types of the White-Eyed Vireo were not specifically depicted in the USGS LULC data (e.g. scrub/shrub), these findings may be misleading and should be further studied with data that address the species habitat needs. This also applies to other species, such as the Prairie Warbler, Northern Bobwhite, and Field Sparrow, that prefer open grassy stands, and the Loggerhead Shrike and Eastern Kingbird, that prefer a more open savanna type habitat. In this study, these species showed a preference for landscapes with a high percentage of agricultural land and smaller forest patches with less core area with more edge and unnatural man induced shapes. Again, these findings are probably the result of the lack of scrub/shrub and grassland habitat classes for these species, thus limiting the bird-to-landscape associations for these birds. Future research

should address these edge and scrub, and field-edge species with pertinent data. One example of a dataset that could be used includes the USGS National Land Cover Data set which was developed from 30 m Thematic Mapper (TM) data. This dataset was developed in the 1990's and includes classifications for categories such as shrubland, grasslands/herbaceous, as well as specific forest and agricultural categories. Future research would provide a comparison of the applicability of the finer grained datasets for the purposes of habitat suitability assessment.

Conservation Implications

It has been observed that conservation and resource management should be based at least as much on science as on politics and economics. It has also been noted that it is important to continue to study bird populations in order to conserve them, as information on how populations respond to landscape change is available for very few species (Wiens 1994). The current research is part of an effort to address this need. The results of the current study, as well as others studies that have focused on the landscape scale, have varied dramatically between species, implying that separate conservation guidelines for each species must be generated (Rosenberg et al. 1999).

This research and others (e.g. Donovan et al. 1997, Howell et al. 2000, Dettmers and Bart 1999) supports the position that a good first approximation for assessing habitat suitability for certain species is to assess habitat characteristics at the landscape scale. With the use of GIS and remotely sensed data, relatively inexpensive mapping applications can be developed at the landscape scale. Assessment of the amount and

configuration of habitat over large areas, in a manner that is neither labor intensive nor prohibitively time-consuming, holds many benefits for mangers and researchers working on large-scale issues (Dettmers and Bart 1999). This is fortunate, since detailed data on plant species composition or structure is seldom available for large areas.

A first approximation assessment of habitat suitability can be developed at the landscape scale by using spatial pattern metrics developed from kilometer scale landcover data. This is useful in determining the relative importance of areas for conservation efforts and in assessing the impact of alternative management plans that could alter or remove habitat for bird species. For example, results of the current study and others show that, at the landscape scale, the Wood Thrush was primarily associated with habitat composition and forest configuration (Fauth 1997, Robbins et al. 1989). Therefore, as a first step in assessing suitable habitat for the Wood Thrush, habitat composition and forest configuration metrics developed from broad scale data can be examined for a regional area. Pertinent sites from the broad scale first approximation assessment could be further assessed in terms of habitat vegetation and structure variables. For example, Wood Thrush abundance is known to be sensitive to habitat vegetation and structure variables, such as stems less than 2 cm, number of logs, and stems greater than 50 cm (Howell et al. 2000).

This study provides the basis for an improved understanding of the influence of landscape structure on bird species population changes. Past attempts to explain population declines of migrants detected by BBS data have been complicated by a variety of factors, including a lack of information on existing vegetation and on possible long-

term changes in vegetation (James et al. 1992). The methods and models developed in the current study are useful in determining the role of habitat fragmentation in causing population declines shown in the BBS data. The models generated for the forest interior and forest interior/edge species ($R^2 > 35\%$) may be directly applicable to determining the degree to which landuse changes around BBS routes affect habitat suitability and may offer partial explanations for the long-term population changes in these species. It is widely recognized that population declines are at least partially attributable to habitat fragmentation. Findings from the current study, as well as other recent studies (e.g. Rosenberg et a. 1999, Donovan et al. 1997, Howell et al. 2000, McGarigal and McComb 1995, Bolger et al. 1997) provide empirical evidence that habitat suitability, as quantified by landscape metrics, is associated with bird species abundance. Future research of this type could help refine conservation guidelines to address how fragmentation of the landscape affects bird species populations.

Limitations of the Study Approach

A potential limitation of this study is the quality of the existing BBS data. A potential bias is introduced in the data set by the fact that the survey process most frequently counts species characteristic of roadsides, with the species that sing loudest and most frequently being the easiest to detect. Also, volunteers vary in their ability to hear, identify, and estimate the abundance of birds (Sauer and Droege 1990). In the current study, this makes it difficult to determine if there is indeed little or no association in the models with low R^2 values, or if the species is just not well documented in the BBS data. A further criticism of the survey is that the BBS is a roadside survey, and habitat

changes along roadsides may not be representative of regional habitat changes. Additionally, many habitats are not well covered, and the species that specialize in those habitats, such as wetland birds, are poorly sampled.

It was initially thought that the partial BBS route data might provide a finer level of detail and perhaps improve the analytical results in this study. However, the lack of bird counts on the partial routes for most of the species seemed to confound rather than improve the results. In fact, 60% of the birds studied were not counted at all on at least 30% of the partial routes. Also, the lack of an exact geographic location of each partial route required an assumption of spatial pattern metrics that coincided with 5 equally divided pieces, which may not have represented the true locations used by the volunteers. Prior research supports the concept that the BBS data for entire routes be used. For example, population trend analyses have typically been based on yearly counts for entire routes (Robbins et al. 1986), and comparisons between observers found almost identical species total for the entire 50 stops but not for the individual stops (Robbins et al. 1986).

A second limitation of this study is the USGS LULC classification scheme. The classification scheme of the USGS LULC data was not developed with the habitat requirements of specific wildlife species in mind (Hepinstall and Sader 1997). The classification scheme appears adequate for the forest interior and forest interior/edge species, but is deficient for the species that prefer scrub/shrub or other categories not differentiated in the USGS LULC data. This lack of specificity may explain the relatively weak ability of the composition component incorporating the classification variables to account for the variance in bird species abundance that prefer the scrub/shrub habitat.

Also, local scale vegetation characteristics were not included in this study and hence this study does not provide managers a perspective on the relative importance of local versus landscape scale habitat for the bird species. Local scale habitat typically includes variables to describe the local vegetation structure, such as number of living stems in different size classes, percent canopy cover, and percentage of downed logs. Studies such as Knick and Rotenberry (1995), Bolger et al. (1997), Howell et al. (2000), and Pearson (1993), have incorporated both landscape and local habitat variables. As might be expected, the strength of the results for some of the species in the studies rose with the addition of the local habitat variables.

A third limitation of this study is the uncertainty involved in selecting the best extent for use in spatial pattern metric calculation. Both 0.4 km and 10 km extents were used in the analysis, with the 0.4 extent apparently providing the best results. The inclusion of the wide extent was supported by prior findings indicating that a 10 km radius best explains the distribution of cowbirds and encompasses the average distance moved by female cowbirds during the breeding season (Howell et al. 2000). In contrast to studies by Robinson et al. (1995), and Howell et al. (2000), the current study did not provide strong results for the 10 km extent. The designation of the 10 km radius makes intuitive sense for the Robinson et al. (1995) study, which actually looked at nest parasitism by the Brown-headed Cowbird. However, for studies such as the current study and Howell et al. (2000), the rationale for the designation of a 10 km radius is not as meaningful, since the specific purpose was not to assess nest predation or brood parasitism by the Brown-headed Cowbird.

A fourth limitation of this study is the interpretation of the results of the statistical analysis. Care must be exercised in interpreting results of the stepwise regression and logistic regression. While the regression models cannot be interpreted as cause and effect, they can demonstrate the relative importance of each of the components included in the models. The landscape features selected by a species may be masked by averaging spatial pattern measures. All BBS routes used in this study included different habitat types with different patch distributions. The spatial pattern metrics are means per route or partial route and provide an overall picture of the landscape structure; however, variability within a route may be masked by the mean. This statistical technique does however provide an important first means of assessing variation in species abundance at various spatial extents and provides an overall picture of landscape habitat characteristics. It can be expected that extensive detailed studies of each species would reveal finer mechanisms of habitat selection.

Suggested Refinements in the Method

The BBS data were utilized in this study with the full realization that there are several potential sources of bias in the data set. In spite of these limitations the unique geographic and temporal extent of the BBS data provides a strong argument for its utilization. It is recommend that the species with models with $R^2 > 35\%$ should be studied further, particularly for areas that have temporal BBS and landscape data. If applicable to the species, additional landscape variables, such as elevation and isolation variables such as nearest neighbor distance, could be added to the analysis. The models generated could then be applied to the landscape data for different timeframes to

determine if the information can be used to explain population declines as seen in the BBS in terms of habitat suitability. Nevertheless, the R^2 values will still probably be moderate. If stronger associations are to be expected, the bird census data will need to be designed and selected for the particular species at hand.

The analytical technique used in this study could also be refined by improvements in the categorization of the landcover data set. Categories that reflect the specific landscape requirements of the birds under study should improve the results of the analysis by capturing the pertinent variation. This is particularly needed for the species that prefer scrub/shrub or other categories not differentiated on the USGS LULC data set. The current category in the USGS LULC data set most closely affiliated with these birds is the category of rangeland (land where the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs). However, this category makes up less than 1 % of the landcover/landuse in the study area. Most of the rangelands in the US are in the western range (Anderson et al. 1976). Also, because the same 12 independent variables of landscape structure were used for all 15 bird species, various important variables such as elevation, standing water, and local scale vegetation variables that strongly influence the distribution of some birds, were not included. For these reasons, the R^2 values are relatively low for all species, and the statistical models generated have limited utility in predicting bird abundance.

The method of analysis can be further refined by careful consideration of the scale and extent used in the analysis. If a study considers a mixture of bird species, as is addressed in this research, defining the area or extent that corresponds to a single scale

for all species can be a challenge. There is apparently no single best scale for investigating avian communities and landscape structure. Both narrow and wide spatial extents were used in this study. The narrow buffer distance, which coincided with the BBS design, provided the best statistical results. Ideally, the buffer extent used should represent the landscape over which the birds detected are breeding. The buffer extents used in this study represented a compromise, since determining the extent of the breeding area is dependent on a complex interaction of the species requirements and the makeup of the landscape itself. The selection of a buffer more in line with the species home ranges, if known, is more meaningful. For example, the home range for the Wood Thrush is approximately 150m, about 1.2 km for the Prairie Warbler, about 1.8-2.1 km for the Loggerhead Shrike, and about .8-1.6 km for the Northern Bobwhite (Hamel 1992). These figures are more in line with the narrow extent of .4 km rather than 10 km. Since the home ranges varied for the species in the current study, and the home range was unknown for over 50% of the species studied, the home ranges were not used in this study. However, in future studies, it may be better to concentrate on a specific species or group of species with similar habitat needs and home ranges. Regardless, the 10 km buffer appeared excessive and an intermediate buffer, regardless if the homerange is known, would provide a better reference in future research.

The definition of the extent over which the landscape metrics are calculated determines the division of polygons when the area is clipped from the broader database. In this study, the most dramatic effect of the difference in the narrow and wide buffer extents was related to patch size, patch density, and edge density. The patches in the

narrow buffer areas had a greater chance of being divided when the area was clipped from the USGS LULC database. This is illustrated in Figure 23, which shows the narrow and wide buffer areas around a partial BBS route. It demonstrates how one large forest patch was divided into smaller patches as it was clipped from the narrow and wide buffer extents. Turner et al. (1989, 1990) and Wiens (1989) had investigated this in prior research, concluding that quantitative changes in measurement across spatial scales will differ according to how scale is defined. Thus, the definition of scale, in terms of extent and grain, is an important consideration in landscape scale studies. Unfortunately, there is no single best scale for investigation of all avian species and landscape patterns. The proper scale is dependent on the objective of the analysis, the specific species and habitats involved, and the processes that are believed to be important. One errs not by advocating that a particular scale may be useful for examining bird species patterns, but by forcing investigations of specific patterns into a scale of analysis that is improper (Wiens 1989). It is possible that the methods used in the current research could be improved by further investigation of the optimum scale. By varying the scale used in the study, utilizing a finer grained dataset and an intermediate extent, the further research would likely provide a more unified understanding of how the change in scale affects the associations. This in turn, might shed light on the selection of the scale that is appropriate for a given investigation and improve the method of analysis.

Summary and Conclusions

This study has determined that landscape spatial patterns from broad scale data are useful indicators of habitat suitability for the species under study. However, the

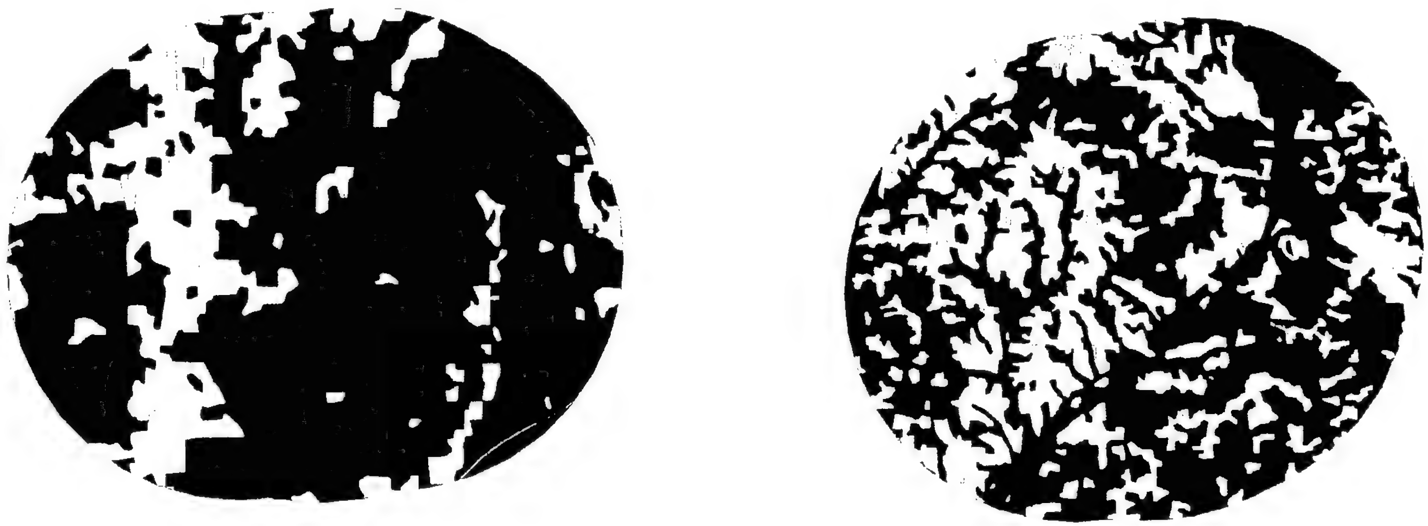
multiple regression analysis indicated wide variation among the species in how spatial pattern metrics affected the species abundance. For five of the species examined, the spatial pattern metric models generated are appropriate for the assessment of the relationship of landscape changes and population declines.

This research determined that a comprehensive set of landscape metrics provides a way to produce an all-encompassing quantitative description of the landscape. The landscape structure was quantified using a suite of 12 spatial pattern metrics calculated from USGS LULC data. The metrics for all routes were pooled and summarized into uncorrelated landscape structure components using principal components analysis (PCA) techniques. Multiple regression techniques showed that 3 components, landscape composition, forest configuration, and landscape diversity/interspersion, are important in the abundance of some of the bird species.

The unexplained variance (>50%) of the models developed in this study probably reflects the inherent variability introduced by the utilization of the existing sources of bird and landscape data. The existing BBS data, which may be biased toward roadside birds that sing loudest and most frequently, may also be confounded by unknown variability among volunteer observers. Also, the existing classification scheme of the USGS LULC data was not developed with the habitat requirements of specific wildlife species in mind and, as such, appears adequate for some of the forest interior and forest interior/edge species, but not for scrub/shrub species. Another possible source of variability is the suboptimization of the extent selected for use in the spatial pattern metric calculation.

It can be concluded from this study that spatial pattern metrics from broad scale data are appropriate for assessing habitat suitability; however, with low to moderate R^2 values. If stronger associations are to be expected, bird census data will need to be designed and selected for the particular species at hand. Also, landcover categories that reflect the specific landscape requirements of the birds under study should improve the results of the analysis by capturing the pertinent variation. This will require a finer grain dataset that can differentiate the specific landcover types. The analysis might also be improved if an intermediate buffer radius was used, since this research was constrained by the physical extent of the landscape study area. Ideally, the buffer extent used should represent the landscape over which the birds detected are breeding. The selection of a buffer more in line with the species home ranges, if known, would be most meaningful. In future studies, it may be better to concentrate on a specific species or group of species with similar habitat needs and home ranges.

The conservation of bird populations is of great importance. Conservation strategies to reverse the declines of forest bird populations will require knowledge of habitat requirements across the range of species. It has been concluded from this study that spatial pattern metrics from broad scale data can provide a good first approximation for assessing habitat suitability. This provides an important avenue towards proper assessment of habitat suitability and towards the development of broad-scale conservation management practices.



A

BBS Route 38 in AL

B

BBS Route 32 in AL

Spatial pattern metric	A	B
Mean Patch Size	2000.00	2000.00
Total Core Area Index	77.00	37.00
Edge Density	6.60	17.00
Patch Density	.04	.03
Mean Shape Index	1.56	2.40

Legend

Nonforested Area

Forested Area

Figure 22. Landscape configuration metrics for two sample landscapes that have the same mean patch size.

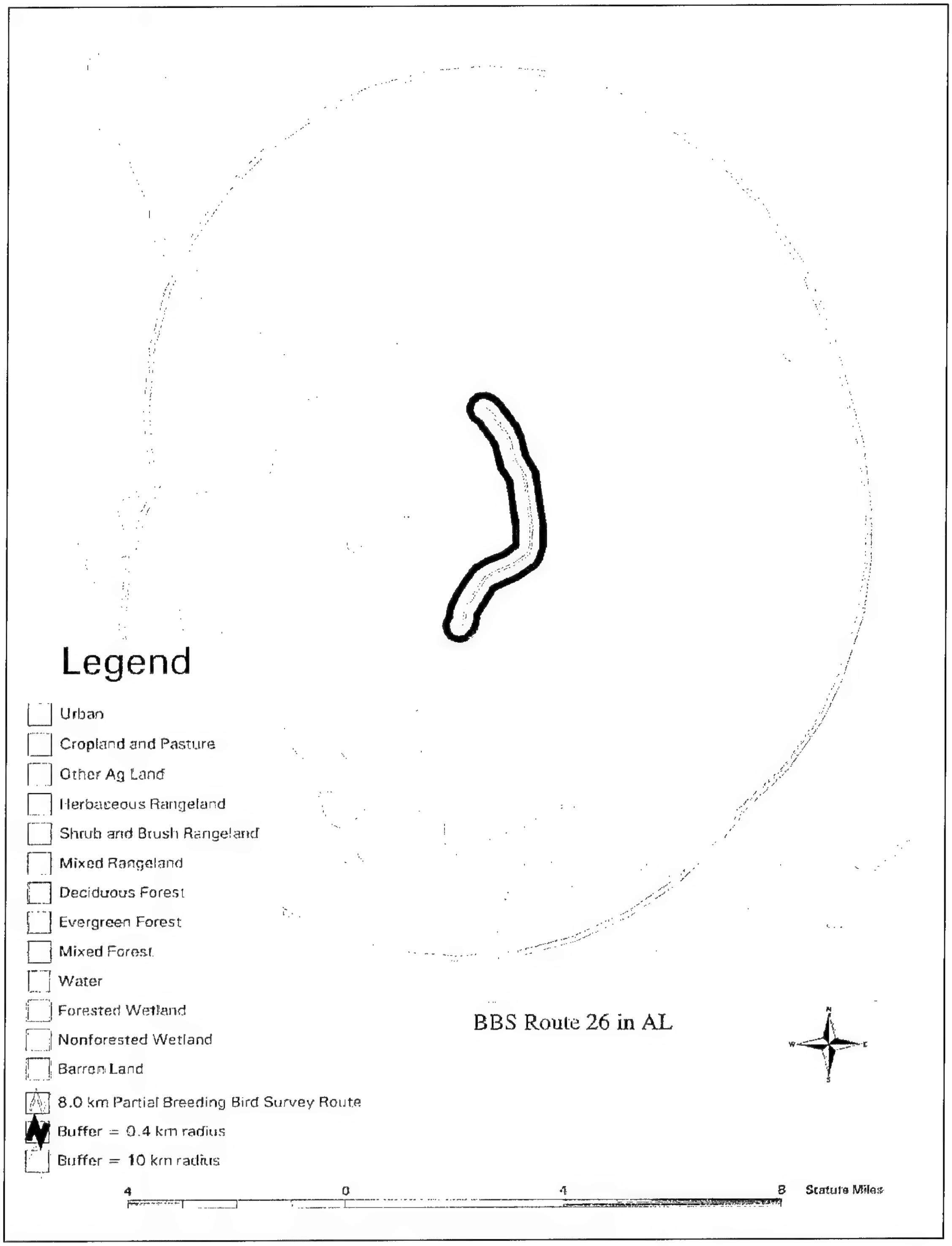


Figure 23. One 5 mile partial breeding bird survey route with a 0.4 and 10 km buffer radius, with USGS land use/land cover data shown in the background.

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APPENDIX A

BIRD HABITAT AND TRENDS

The following provides a description of the preferred habitat of the 15 species studied in this research. A description of the species population trends is also discussed.

Prairie Warbler (6730)

This species is often listed as an example of alarming decline among Neotropical migrants. The Prairie Warbler breeds in shrubby old fields, early-stage regenerating forests, and other early successional habitats. Based on BBS data for physiographic regions, 11 showed decreases and 2 showed increases. The region that includes this study area showed declines only in uplands. Lowland populations were stable, and even increased in certain areas (James et al. 1992). Since colonial times, deforestation has created extensive breeding habitat, which is now being lost to urbanization and reforestation. Suppression of fires, which permits forest regeneration may play a factor in habitat loss (Nolan 1999).

Northern Bobwhite (2890)

The Northern Bobwhite, a non-migratory bird that is considered to be one of North America's most important game birds, is widely distributed throughout the eastern US and Mexico. Its preferred habitat includes agricultural fields, grasslands, open parklike pine and mixed pine-hardwood forests. According to BBS data, Christmas Bird Count, and state game agencies, there is evidence of widespread decline throughout the US (Brennan 1999). Annual declines from 1966-1988 averaged 3% in eastern US, 0.7% in central US, and 1.8% overall in US (Droege and Sauer 1990). The declines are primarily attributed to habitat loss from changing land uses in agriculture, forestry, and expanding sububanization. Specifically, the clean farming with nearly all weeds

removed and high-density pine plantations have had negative habitat results. Also, changes in forestry and agricultural land use have resulted in fragmentation of the Northern Bobwhite's habitat on a broad landscape scale (Brennan, 1999). Frequent vegetation disturbance from prescribed fire and mechanical disturbances is needed for maintaining Bobwhite populations (Landers and Mueller 1986).

Field Sparrow (5630)

The field sparrow breeds in scattered samplings or shrubs in weedy habitats, overgrown fields, wood margins, hedgerows, and thickets of the eastern US and southern Canada. It is a partial migrant, with some remaining in their breeding grounds in the winter while others move farther south. For the study area, it is considered a non-migratory species. According to the BBS data, there has been a nationwide decline of 3.4% per year between 1966 and 1991. Changes in land use are the primary factors affecting numbers. The presence of suitable habitat is necessary to maintain local populations (Carey et al. 1994).

Loggerhead Shrike (6220)

Throughout most of the southern part of its range, which includes the study area, the loggerhead shrike is resident. It inhabits open habitats with short vegetation, such as grasslands, pastures with fencerows, mowed roadsides, agricultural fields, riparian areas, and open woodlands. According to the BBS data, there is a current decrease of about 3.5-5%/yr across the range. This is one of the few species to show significant declines in most states, provinces, and physiographic strata of the continent (Robbins et al. 1986).

Population loss can be partially attributed to declines in hay crops, pasture land, and hedgerows (Yosef 1996).

Eastern Kingbird (4440)

The Eastern Kingbird is the most widely distributed of the kingbirds that breed north of Mexico. It is a migratory, aerial hawking insectivore that breeds in open environments, usually in fields with scattered shrubs and trees, and along woodland edges in forested regions. According to the BBS, the data indicate that the continental population of the kingbird didn't change significantly between 1966-1991. By region, though, several significant trends appear: no significant changes in abundance in eastern, central or w. North American from 1966-1991, but from 1982-1991 abundance in e. North America declined significantly, but also increased significantly in central and western regions. Since 1982, trends have shown significant recoveries in Alabama, South Carolina, and Tennessee, but most states continue to show declines. Population declines in east and south North America are probably caused by habitat loss resulting from human development and natural plant succession. The decline of small farms since the 1960s-1990s has resulted in the loss of open space. Forest succession has also resulted in the loss of significant habitat (Murphy 1996).

White-eyed Vireo (6310)

The preferred habitat of the White-Eyed Vireo is dense secondary deciduous scrub, wood margins, and overgrown pastures. It is a migratory songbird that is primarily detected by ear than by eye. Based on BBS data, significant declines in numbers over its range was –0.72% per year for the long-term period (1966-1988) and –2.99% and for the

short-term period (1978-1988). In the eastern US they found significant short-term but not long-term declines. Nesting areas are frequently cleared by humans. With significant declines in the White-eyed Vireo population in some regions, it is suggested that some measures, such as promoting suitable scrub habitat either by leaving open areas to grow or by opening some forested areas through partial cutting, be addressed. The measures have not been tested (Hopp et al. 1995).

Eastern Wood-Pewee (4610)

The Eastern Wood-Pewee is a migratory species that breeds in wooded habitats of the eastern US and Canada. It breeds in virtually every type of wooded habitat in the east, from urban shade trees, roadsides, woodlots, and orchards to mature forest (McCarty 1996). BBS data show a significant decrease in population from 1965-1993 (Robbins et al. 1986). Declines of 35.6% were found during 1966-1993 while there was a 13.4% decline from 1984-1993 (Price et al. 1995). The species uses both edge and forest interior for breeding. It is apparently not sensitive to forest fragmentation when choosing breeding sites (Blake and Karr 1987). Heavy browsing of forests by white-tailed deer may play a part in its decline.

Yellow-throated Vireo (6280)

The Yellow-Throated Vireo is a migratory species that breeds in the eastern US in edge habitats of both bottomland and upland deciduous and mixed deciduous-coniferous forests. Habitats include forest edges of streams, rivers, swamps, treefall gaps, and roads, and woodland habitats of parks and towns (Rodewald and James 1996). The species has disappeared or decreased at several small forest reserves in the eastern US (Askins et al.

1990). Overall population trends from the BBS data showed significant increase of 1.1%/year during 1966-1994. During this timeframe, species increased 1.3%/year in the eastern part of the range, but declined 0.9%/year in the central region. While this species is often associated with forest edge habitat, large blocks of forest are necessary for successful breeding. Extensive clear cutting will adversely affect the species (Rodewald and James 1996).

Hooded Warbler (6840)

The Hooded Warbler is a small migratory songbird that breeds in southernmost Canada and the eastern US and winters in Central America. It prefers mixed hardwood forest in the north and cypress-gum swamps in the south. It is considered a forest-interior species because it is restricted to larger woodlots. It is declining in only a few parts of its breeding range (Evans Ogden and Stutchbury 1994). According to BBS data, regionally there is much variation in the population trends. From 1966-1991, Georgia was the only state to show a significant decrease. For the Easter Region of BBS, there was a significant long-term increase (1.58%/yr) (Sauer and Droege 1989). In Canada the species is considered threatened because suitable habitat is becoming increasingly scarce and fragmented. Since the Hooded Warbler is an area-sensitive forest songbird, it is threatened on breeding grounds primarily by forest fragmentation (Evans Ogden and Stutchbury 1994).

Wood Thrush (7550)

The Wood Thrush is a Neotropical migratory bird. Its preferred habitats includes interior and edges of deciduous and mixed forests, especially well-developed, uplands. It

is more likely to occur in larger-area forests. BBS continent-wide data show significant decline in abundance of 1.7% per year from 1966-1994 (Sauer and Droege 1992). Fragmentation of forests is possible cause for decline (Roth et al. 1996).

Yellow-billed Cuckoo (3870)

The Yellow-billed Cuckoo is a migratory bird that breeds in deciduous forests, bottomland woods, woodland thickets, and other hardwood forests. It generally avoids coniferous woods. It prefers extensive forests (Hamel 1992). From 1980 to 1994, populations declined in most states. Eastern US populations suffered 3.2% annual decline. The species is sensitive to habitat fragmentation and degradation of riparian woodlands due to agricultural and residential development (Dobkin 1994).

Kentucky Warbler (6770)

The Kentucky Warbler is a migratory species that breeds primarily in the southeastern US. It prefers rich, moist, deciduous forests, and bottomland hardwoods. Studies of forest fragmentation in Missouri indicate that blocks of suitable habitat (at least 500 ha) are necessary for successful breeding (Gibbs and Faaborg 1990). It is rarely observed in agricultural habitats. BBS data suggest that since 1980 the Kentucky Warbler's continentwide population has been slowly decreasing, however, local increases and range expansion also seem to be occurring (McDonald 1998). Forest management practices that promote a dense understory and ground cover should enhance habitat for this species (Bushman and Therres 1988).

Brown-headed Nuthatch (7290)

The Brown-headed Nuthatch is a non-migratory bird that lives in pine forest of the southeastern US (Withgott and Smith 1998). According to BBS data, between 1966 and 1996, there has been a significant -2.2%/year decline throughout the range (Sauer et al. 1997). The decline is primarily attributed to the altered pine forests by commercial logging. Old-growth pine forest is almost gone, with even-aged stands of younger pines replacing them. Fire suppression has also negatively affected habitat suitability allowing hardwood to flourish (Engstrom et al. 1984).

Prothonotary Warbler (6370)

The Prothonotary Warbler is a migratory species that breeds primarily in the southeastern US. It prefers bottomland hardwood forests and is considered an interior species. BBS data indicated significant overall decreases of -1.6% annually, between 1966 and 1996. Declines are attributed primarily to loss of habitat. Bottomland hardwood forests have been logged or converted to pasture cropland throughout the southeastern US (Petit 1999).

Brown-headed Cowbird (4950)

The Brown-headed Cowbird is North America's most well known brood parasite. For the study area, it is considered a non-migratory species. Its preferred habitat includes open woods, margins, thickets, agricultural and residential areas. BBS data show for the timeframe between 1965-1987 significant increases for Georgia, North Carolina, Iowa, North Dakota, Utah, Colorado and significant decreases for Minnesota, Michigan, Wisconsin, New York, Rhode Island, Ohio, Ontario, West Virginia, Tennessee, New

Brunswick, Oklahoma, Texas and Oregon. Because of forest fragmentation increases edge and provides access, forest interior species have become exposed to the Brown-headed Cowbird (Lowther 1993).

Bird Abundance

Table A1 lists the mean yearly abundance for each species for each full BBS route, while Table A2 lists the mean yearly abundance for each species for each partial BBS route.

Table A1. Mean yearly abundance for each species for each of the 53 full BBS routes.

State	Rt	AOU Number														
	#	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
AL	1	1.8	39.2	14.2	2.4	4.6	6.6	8.0	0.0	0.0	10.6	14.4	0.6	0.0	1.6	7.6
AL	10	0.7	30.3	3.7	1.0	2.3	1.0	1.3	0.0	0.0	12.3	9.3	0.3	3.0	0.0	2.3
AL	11	2.8	49.0	12.5	2.3	2.5	6.0	4.3	0.0	0.0	9.3	4.8	1.0	1.0	0.0	4.5
AL	12	0.6	13.6	1.4	0.0	1.4	1.4	1.2	2.2	2.6	12.6	5.6	5.2	1.2	0.2	2.6
AL	13	3.8	31.2	6.4	2.6	3.6	8.6	5.6	0.8	0.6	7.6	3.0	2.0	2.6	0.4	7.8
AL	15	4.0	41.8	12.2	1.2	1.8	3.6	3.6	1.0	0.4	5.6	5.6	0.8	0.4	0.2	1.6
AL	16	3.4	48.4	10.8	1.0	5.2	11.4	7.6	2.8	0.4	14.4	10.6	1.4	0.8	0.4	7.2
AL	17	12.0	14.4	6.0	0.4	4.8	14.8	2.6	4.8	6.4	25.8	13.4	6.4	4.4	1.6	13.6
AL	2	3.0	64.2	25.2	5.2	7.0	6.2	7.8	1.0	0.6	18.0	17.6	2.8	0.0	0.0	25.0
AL	22	0.0	75.6	0.0	7.4	10.0	3.2	1.4	0.0	0.2	3.6	8.2	2.4	1.4	0.2	13.8
AL	23	7.0	45.6	2.0	4.4	10.0	19.4	12.0	1.0	3.0	19.0	14.8	4.6	3.4	6.8	7.6
AL	24	1.4	58.4	2.2	4.0	15.2	2.4	3.4	0.0	0.0	8.8	7.0	0.0	4.0	2.0	12.6
AL	25	4.3	67.0	15.0	1.3	11.7	10.3	2.3	1.0	2.0	17.7	11.3	1.7	2.0	0.3	22.7
AL	26	0.8	59.6	1.6	1.2	4.4	1.4	3.0	0.0	0.0	7.6	11.8	0.4	1.6	3.6	6.8
AL	28	11.8	57.2	9.0	1.6	22.2	8.6	12.2	1.0	4.0	25.0	8.0	2.4	9.0	1.2	8.6
AL	29	3.6	65.4	8.4	5.2	21.6	10.8	7.4	1.2	2.4	11.2	7.2	3.6	10.6	2.2	10.0
AL	30	0.2	49.2	1.4	10.2	6.8	2.0	0.0	0.0	0.0	0.4	1.0	0.0	0.0	1.2	0.0
AL	31	2.8	70.0	1.0	17.8	20.8	4.3	0.0	0.0	0.3	2.8	10.3	1.3	0.0	0.3	2.0
AL	32	1.3	48.5	12.8	15.0	15.5	3.3	0.3	0.5	0.0	6.5	6.3	0.0	0.3	0.5	2.3
AL	34	4.6	81.8	8.0	14.4	8.0	13.8	6.2	1.6	3.0	21.4	16.6	1.4	4.0	0.6	19.4
AL	35	2.0	33.0	0.0	1.0	2.8	12.0	2.3	1.0	2.3	3.8	10.3	0.0	7.5	1.8	1.5
AL	36	2.8	25.8	1.6	0.4	6.8	15.6	6.8	2.0	6.4	19.6	10.4	3.0	1.2	3.8	4.6
AL	37	0.4	48.4	0.2	3.2	3.8	26.6	4.0	0.0	4.8	23.2	12.4	0.0	1.8	0.2	0.0
AL	38	2.0	32.3	0.0	1.7	10.0	20.0	3.7	4.0	1.7	10.7	13.7	1.7	3.7	1.7	9.3
AL	4	0.0	59.7	13.3	5.7	4.3	3.7	4.3	0.0	1.0	6.0	7.3	1.0	2.3	0.0	3.0
AL	41	0.0	15.5	0.0	0.0	4.8	7.0	0.0	0.0	1.5	2.3	5.0	0.0	5.5	2.8	2.3
AL	43	7.4	18.0	3.8	2.4	7.6	9.6	10.4	2.6	2.2	13.6	14.0	5.6	2.6	0.0	15.4
AL	44	0.0	7.4	2.4	0.2	0.4	0.6	0.2	0.0	0.0	1.2	0.0	0.0	0.0	0.0	10.6
AL	5	2.2	27.8	8.2	3.8	4.0	3.4	3.0	0.0	0.0	3.0	1.0	0.6	1.8	0.0	4.4
AL	6	0.2	31.2	24.4	2.2	4.0	1.6	3.0	0.0	0.0	11.8	12.0	0.0	0.0	6.8	6.8
AL	7	4.0	23.0	25.0	0.8	4.0	9.5	0.3	1.3	0.0	3.8	18.8	0.8	0.0	0.0	9.3
AL	8	4.8	47.8	13.8	0.4	7.0	2.0	3.6	0.0	0.2	10.6	7.6	0.8	1.4	0.0	12.0
AL	9	2.0	24.8	37.6	1.0	5.2	4.6	2.4	0.0	0.6	13.4	3.2	1.2	0.0	0.0	14.6

Table A1. (cont'd) Mean yearly abundance for each species for each of the 53 full BBS routes.

State	Rt	AOU Number														
	#	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
FL	1	0.2	56.4	0.0	9.4	8.0	12.8	0.0	0.2	0.6	4.2	12.2	0.4	3.8	3.0	1.8
FL	2	0.0	2.4	0.0	0.0	0.6	1.6	0.4	0.0	0.0	0.2	0.4	0.0	0.4	0.0	1.8
FL	3	0.0	23.8	0.0	1.2	2.4	2.4	0.0	0.2	0.6	2.4	11.0	0.0	0.6	2.6	3.0
FL	4	0.0	36.8	0.0	2.6	3.0	3.6	0.4	1.2	1.8	1.2	6.2	0.0	2.8	2.0	3.0
FL	5	0.0	22.4	0.0	0.6	5.8	9.8	0.8	0.2	4.0	1.2	7.8	0.0	5.8	16.4	1.4
FL	6	1.4	54.8	11.8	2.0	16.8	10.0	4.0	4.6	2.4	1.0	2.4	0.6	0.8	0.6	2.6
FL	7	1.4	37.8	0.0	5.2	5.2	17.4	1.4	1.0	4.0	4.0	9.0	0.0	3.4	6.0	2.4
FL	8	0.0	29.0	1.8	3.3	10.5	8.8	0.0	0.0	1.8	0.3	6.0	0.0	0.0	6.8	1.8
FL	9	0.0	5.0	0.0	0.0	1.6	24.0	0.0	0.0	4.0	0.0	2.4	0.4	2.4	7.4	7.2
GA	10	1.0	55.4	8.2	2.6	22.4	4.8	1.2	0.6	3.6	8.2	6.6	3.0	4.6	4.6	10.4
GA	16	0.7	56.0	10.0	3.3	14.3	4.3	3.3	0.0	0.3	9.7	4.3	2.3	5.0	0.0	1.3
GA	22	6.7	53.7	8.3	3.0	10.3	4.7	3.7	0.3	0.7	7.7	10.3	1.7	4.0	0.3	4.7
GA	25	0.0	54.8	1.5	16.0	16.5	1.0	0.0	0.0	0.0	0.3	6.3	0.0	0.0	0.8	1.0
GA	26	1.4	28.8	17.8	0.8	3.4	3.8	7.8	1.4	0.0	11.4	2.4	2.2	2.6	0.4	8.2
GA	28	2.0	48.3	15.3	1.3	15.8	3.5	2.3	1.0	1.3	15.5	14.0	3.3	3.3	1.0	8.8
GA	33	0.0	57.7	8.3	11.3	11.7	4.7	2.3	0.3	1.0	8.3	8.7	2.7	4.0	2.7	8.7
GA	36	6.3	41.7	9.7	2.3	3.3	4.7	6.7	0.0	0.3	12.0	6.3	3.3	1.0	0.0	8.0
GA	37	5.4	35.4	26.8	1.2	7.8	2.0	11.2	3.0	0.0	13.4	3.2	1.8	0.4	0.0	13.0
GA	38	5.4	52.2	5.4	3.2	20.0	6.0	1.4	0.4	2.0	16.4	6.0	1.0	4.0	1.6	18.8
GA	6	0.0	102.6	1.6	8.8	3.0	10.4	0.4	1.6	1.2	5.2	12.6	0.4	0.2	2.4	7.2

Table A2. Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
AL	10	1st	0.0	5.0	1.3	0.0	0.3	0.3	0.3	0.0	0.0	2.3	0.7	0.0	0.3	0.0	0.0
AL	10	2nd	0.0	5.7	0.0	0.3	0.3	0.3	0.3	0.0	0.0	3.7	2.3	0.0	0.3	0.0	0.0
AL	10	3rd	0.7	6.7	1.3	0.0	0.0	0.3	0.3	0.0	0.0	2.7	2.7	0.0	0.3	0.0	0.0
AL	10	4th	0.0	6.7	0.0	0.3	1.0	0.0	0.0	0.0	0.0	2.7	1.0	0.0	1.7	0.0	1.7
AL	10	5th	0.0	6.3	1.0	0.3	0.7	0.0	0.3	0.0	0.0	1.0	2.7	0.3	0.3	0.0	0.7
AL	11	1st	0.0	10.8	2.8	0.0	1.3	1.8	1.0	0.0	0.0	5.8	0.3	0.5	0.0	0.0	0.0
AL	11	2nd	0.8	13.0	4.3	0.8	0.3	1.3	0.5	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0
AL	11	3rd	0.3	9.0	2.5	1.0	0.3	1.0	0.3	0.0	0.0	0.5	1.5	0.0	0.5	0.0	1.0
AL	11	4th	1.8	10.0	2.0	0.3	0.0	1.5	0.5	0.0	0.0	1.5	1.8	0.0	0.0	0.0	0.8
AL	11	5th	0.0	6.3	1.0	0.3	0.8	0.5	2.0	0.0	0.0	1.3	1.0	0.5	0.5	0.0	2.8
AL	12	1st	0.2	6.6	1.4	0.0	1.4	0.8	0.0	0.6	0.4	4.6	1.8	2.0	0.4	0.2	1.0
AL	12	2nd	0.2	4.8	0.0	0.0	0.0	0.0	0.4	0.4	0.0	4.4	1.4	0.4	0.0	0.0	0.6
AL	12	3rd	0.2	1.0	0.0	0.0	0.0	0.4	0.2	1.2	0.4	0.2	0.8	0.4	0.4	0.0	0.6
AL	12	4th	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.6	0.6	0.6	0.0	0.0	0.4
AL	12	5th	0.0	0.6	0.0	0.0	0.0	0.2	0.6	0.0	1.4	1.8	1.0	1.8	0.4	0.0	0.0
AL	13	1st	0.8	2.8	1.2	0.0	0.6	4.0	2.4	0.0	0.6	1.6	1.2	0.6	0.4	0.0	0.4
AL	13	2nd	0.6	5.6	1.2	0.4	0.8	0.8	0.2	0.0	0.0	1.0	0.4	0.0	0.2	0.0	0.8
AL	13	3rd	1.4	10.6	2.0	0.4	0.8	2.2	0.8	0.2	0.0	3.0	0.6	0.4	0.2	0.4	2.4
AL	13	4th	0.8	7.2	1.6	1.0	0.4	1.2	1.8	0.6	0.0	1.2	0.2	0.8	1.0	0.0	1.6
AL	13	5th	0.2	5.0	0.4	0.8	1.0	0.4	0.4	0.0	0.0	0.8	0.6	0.2	0.8	0.0	2.6
AL	15	1st	0.2	9.8	1.6	0.0	0.0	1.4	0.8	0.6	0.0	3.0	2.6	0.4	0.0	0.0	0.0
AL	15	2nd	0.6	10.2	3.2	0.2	0.0	0.4	1.6	0.0	0.0	1.0	1.4	0.0	0.0	0.0	1.0
AL	15	3rd	0.2	7.4	2.8	0.2	0.0	0.6	0.8	0.2	0.0	1.0	0.6	0.2	0.0	0.0	0.0
AL	15	4th	0.6	7.2	1.6	0.2	0.8	0.2	0.2	0.0	0.4	0.4	0.2	0.2	0.0	0.2	0.2
AL	15	5th	2.4	7.2	3.0	0.6	1.0	1.0	0.2	0.2	0.0	0.2	0.8	0.0	0.4	0.0	0.4
AL	16	1st	0.8	7.8	3.4	0.0	1.0	5.4	1.6	0.6	0.0	4.6	4.2	0.0	0.0	0.0	0.6
AL	16	2nd	1.0	12.8	2.6	0.2	2.0	2.6	0.8	0.4	0.0	3.6	3.4	0.4	0.0	0.0	1.4
AL	16	3rd	1.0	13.8	3.2	0.0	1.4	1.0	2.0	0.6	0.0	1.4	1.4	0.4	0.0	0.2	2.2
AL	16	4th	0.4	9.0	0.8	0.2	0.4	1.6	2.4	1.2	0.2	3.4	1.2	0.6	0.6	0.0	0.4
AL	16	5th	0.2	5.0	0.8	0.6	0.4	0.8	0.8	0.0	0.2	1.4	0.4	0.0	0.2	0.2	2.6
AL	17	1st	0.0	1.8	0.6	0.0	2.2	1.0	0.4	0.4	0.8	10.2	4.0	1.4	0.2	0.0	1.2
AL	17	2nd	3.4	4.0	1.0	0.2	0.8	5.0	1.0	0.8	1.2	5.2	4.0	2.6	3.6	0.0	3.0
AL	17	3rd	3.8	2.4	0.2	0.0	0.6	3.8	1.0	1.0	1.8	5.0	3.0	0.8	0.4	1.2	6.0
AL	17	4th	3.4	3.2	3.2	0.0	1.2	2.0	0.2	1.8	0.6	1.8	0.8	0.2	0.2	0.4	3.0
AL	17	5th	1.4	3.0	1.0	0.2	0.0	3.0	0.0	0.8	2.0	3.6	1.6	1.4	0.0	0.0	0.4
AL	1	1st	0.4	8.4	3.0	0.2	1.2	0.8	1.4	0.0	0.0	1.6	2.4	0.0	0.0	0.0	2.6
AL	1	2nd	0.2	9.2	4.8	0.8	0.6	0.6	1.2	0.0	0.0	1.6	4.2	0.0	0.0	0.4	0.8
AL	1	3rd	0.0	9.4	2.4	0.6	1.2	0.0	1.0	0.0	0.0	0.2	2.0	0.0	0.0	0.0	0.4
AL	1	4th	0.6	7.6	2.8	0.0	0.6	2.4	2.0	0.0	0.0	1.6	2.0	0.4	0.0	0.0	2.8
AL	1	5th	0.6	4.6	1.2	0.8	1.0	2.8	2.4	0.0	0.0	5.6	3.8	0.2	0.0	1.2	1.0
AL	22	1st	0.0	22.2	0.0	0.8	2.8	0.0	0.2	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.2
AL	22	2nd	0.0	15.8	0.0	3.4	2.8	1.2	0.0	0.0	0.0	0.6	1.2	0.4	0.4	0.2	2.4
AL	22	3rd	0.0	10.6	0.0	0.4	1.4	0.0	0.0	0.0	0.0	1.0	0.6	0.0	0.0	0.0	3.0
AL	22	4th	0.0	13.0	0.0	1.4	1.4	0.2	0.8	0.0	0.2	1.2	1.6	0.2	1.0	0.0	2.0
AL	22	5th	0.0	14.0	0.0	1.4	1.6	1.8	0.4	0.0	0.0	0.8	2.0	1.8	0.0	0.0	6.2
AL	23	1st	0.2	12.0	0.6	0.2	4.4	4.0	1.0	0.0	1.4	7.2	4.4	2.2	0.4	0.4	0.4
AL	23	2nd	0.2	9.0	0.0	1.2	1.6	4.2	4.6	0.6	0.6	6.0	3.4	1.4	1.4	1.6	3.0
AL	23	3rd	4.4	8.0	0.8	0.0	1.2	6.0	2.6	0.4	0.4	2.8	2.2	0.2	1.2	1.4	0.6

Table A2. (cont'd) Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
AL	23	4th	0.2	9.8	0.0	2.4	2.0	3.0	2.4	0.0	0.4	1.6	3.0	0.4	0.4	0.2	1.8
AL	23	5th	2.0	6.8	0.6	0.6	0.8	2.2	1.4	0.0	0.2	1.4	1.8	0.4	0.0	3.2	1.8
AL	24	1st	0.0	22.0	0.0	0.2	5.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.4	0.0	1.4
AL	24	2nd	0.0	10.6	0.0	0.4	1.6	0.2	0.4	0.0	0.0	3.8	1.8	0.0	0.4	0.6	3.0
AL	24	3rd	0.0	7.8	0.6	0.2	2.0	1.6	1.0	0.0	0.0	3.0	2.6	0.0	1.0	0.2	1.6
AL	24	4th	0.0	8.4	1.4	2.6	2.4	0.2	0.2	0.0	0.0	1.2	0.6	0.0	0.2	0.2	2.8
AL	24	5th	1.4	9.6	0.2	0.6	4.2	0.4	1.8	0.0	0.0	0.8	1.6	0.0	1.0	1.0	3.8
AL	25	1st	0.0	17.3	5.7	0.3	6.3	0.3	0.0	0.0	0.0	5.0	1.7	0.0	0.3	0.0	2.3
AL	25	2nd	0.0	22.7	6.7	0.0	2.3	3.0	0.3	0.0	0.7	3.3	4.0	0.7	1.3	0.0	8.3
AL	25	3rd	0.3	17.3	2.7	0.7	2.3	2.0	0.0	0.0	0.7	2.0	1.7	0.0	0.0	0.3	3.3
AL	25	4th	2.0	6.7	0.0	0.3	0.3	2.3	1.0	0.0	0.3	4.3	1.7	0.7	0.0	0.0	5.7
AL	25	5th	2.0	3.0	0.0	0.0	0.3	2.7	1.0	1.0	0.3	3.0	2.3	0.3	0.3	0.0	3.0
AL	26	1st	0.0	7.0	0.2	0.0	0.8	0.4	0.5	0.0	0.0	2.8	1.8	0.0	0.2	0.0	0.8
AL	26	2nd	0.6	14.6	0.2	0.2	0.6	0.0	0.0	0.0	0.0	1.6	2.4	0.0	0.6	0.0	1.6
AL	26	3rd	0.0	17.6	0.6	0.0	1.0	0.4	0.5	0.0	0.0	0.4	1.6	0.0	0.0	2.0	1.6
AL	26	4th	0.0	10.8	0.0	0.0	0.8	0.2	0.5	0.0	0.0	2.2	3.6	0.4	0.4	1.4	2.0
AL	26	5th	0.2	9.6	0.6	1.0	1.2	0.4	1.5	0.0	0.0	0.6	2.4	0.0	0.4	0.2	0.8
AL	28	1st	0.0	7.4	0.6	0.0	7.8	0.4	3.2	0.0	0.6	10.0	1.2	0.2	2.0	0.2	0.4
AL	28	2nd	0.4	13.4	1.2	0.0	4.6	1.4	3.6	0.2	0.6	5.8	1.8	0.2	1.6	0.0	1.0
AL	28	3rd	6.0	12.2	4.0	0.4	4.4	2.6	3.2	0.2	0.8	2.8	2.2	0.6	2.2	0.0	2.6
AL	28	4th	2.8	11.8	1.6	0.6	4.2	2.0	1.4	0.0	1.0	2.4	1.6	0.6	1.6	0.0	2.2
AL	28	5th	2.6	12.4	1.6	0.6	1.2	2.2	0.8	0.6	1.0	4.0	1.2	0.8	1.6	1.0	2.4
AL	29	1st	0.2	11.2	2.0	1.0	4.6	2.4	0.2	0.2	0.6	4.0	1.6	1.0	0.0	0.6	0.2
AL	29	2nd	0.6	12.6	0.8	1.4	2.8	2.0	2.0	0.6	1.0	2.8	2.0	0.6	1.2	1.0	1.4
AL	29	3rd	2.2	11.6	1.8	0.4	5.4	2.6	3.4	0.0	0.2	2.8	1.2	1.2	4.8	0.2	2.8
AL	29	4th	0.4	19.6	2.4	1.2	5.4	2.6	1.6	0.2	0.4	1.6	1.8	0.8	4.2	0.4	3.0
AL	29	5th	0.2	10.4	1.4	1.2	3.4	1.2	0.2	0.2	0.2	0.0	0.6	0.0	0.4	0.0	2.6
AL	2	1st	0.0	12.0	4.6	0.0	1.8	1.6	2.4	0.2	0.0	6.8	5.4	0.0	0.0	0.0	0.8
AL	2	2nd	1.2	12.4	5.8	0.2	2.2	1.2	3.6	0.6	0.4	6.2	4.2	1.0	0.0	0.0	4.6
AL	2	3rd	1.6	15.4	9.8	0.6	1.2	2.6	1.2	0.2	0.2	3.0	5.2	1.6	0.0	0.0	4.0
AL	2	4th	0.2	15.0	2.2	0.2	0.4	0.6	0.6	0.0	0.0	1.4	2.4	0.0	0.0	0.0	8.6
AL	2	5th	0.0	9.4	2.8	4.2	1.4	0.2	0.0	0.0	0.0	0.6	0.4	0.2	0.0	0.0	7.0
AL	30	1st	0.0	11.6	0.0	0.4	3.6	0.2	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0
AL	30	2nd	0.2	12.0	0.4	3.0	0.4	0.2	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
AL	30	3rd	0.0	10.6	0.8	1.8	0.4	1.6	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.2	0.0
AL	30	4th	0.0	8.2	0.0	2.8	1.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
AL	30	5th	0.0	6.8	0.2	2.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AL	31	1st	1.0	14.3	0.3	0.8	4.5	0.5	0.0	0.0	0.0	0.3	2.8	0.0	0.0	0.0	0.0
AL	31	2nd	0.5	13.5	0.5	1.5	4.5	2.0	0.0	0.0	0.0	1.5	2.0	0.3	0.0	0.0	0.8
AL	31	3rd	0.3	16.8	0.0	5.3	3.8	0.3	0.0	0.0	0.0	0.0	1.8	0.5	0.0	0.0	0.5
AL	31	4th	0.8	18.0	0.3	8.0	5.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.8
AL	31	5th	0.3	7.5	0.0	2.3	2.8	1.5	0.0	0.0	0.3	1.0	2.8	0.5	0.0	0.3	0.0
AL	32	1st	0.0	10.3	1.0	3.8	5.0	0.3	0.0	0.0	0.0	2.3	1.8	0.0	0.0	0.0	0.3
AL	32	2nd	0.0	10.8	2.0	2.0	2.5	0.3	0.0	0.0	0.0	2.5	2.0	0.0	0.0	0.0	0.0
AL	32	3rd	0.8	9.8	6.3	4.5	1.3	0.8	0.3	0.3	0.0	0.3	0.5	0.0	0.0	0.5	0.8
AL	32	4th	0.5	11.5	2.5	2.5	3.8	1.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	1.0
AL	32	5th	0.0	6.3	1.0	2.3	3.0	1.0	0.0	0.3	0.0	1.0	1.0	0.0	0.3	0.0	0.3
AL	34	1st	0.0	25.8	0.0	7.2	2.0	1.0	0.0	0.0	0.0	6.4	2.8	0.4	0.0	0.6	4.4
AL	34	2nd	0.6	23.8	6.2	2.6	1.0	4.0	2.0	0.6	0.8	4.8	3.6	0.0	3.2	0.0	3.8
AL	34	3rd	0.4	13.4	0.4	2.2	2.2	3.8	1.2	0.0	0.8	2.8	2.2	0.0	0.2	0.0	1.4

Table A2. (cont'd) Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
AL	34	4th	1.8	10.6	1.2	1.6	1.6	2.0	1.2	0.0	0.4	4.8	3.2	0.2	0.2	0.0	2.8
AL	34	5th	1.8	8.2	0.2	0.8	1.2	3.0	1.8	1.0	1.0	2.6	4.8	0.8	0.4	0.0	7.0
AL	35	1st	0.0	8.5	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.5	1.3	0.0	0.3	0.0	0.3
AL	35	2nd	0.3	10.5	0.0	0.3	0.8	4.8	0.0	0.5	1.0	1.0	3.0	0.0	0.3	0.8	0.0
AL	35	3rd	0.0	4.5	0.0	0.0	0.8	4.0	0.3	0.5	1.0	1.5	2.3	0.0	2.5	0.3	0.8
AL	35	4th	1.8	4.3	0.0	0.3	0.0	2.5	0.8	0.0	0.3	0.0	1.8	0.0	3.8	0.0	0.0
AL	35	5th	0.0	5.3	0.0	0.5	0.8	0.8	0.3	0.0	0.0	0.8	2.0	0.0	0.8	0.8	0.5
AL	36	1st	0.0	4.6	0.2	0.0	1.6	6.2	3.0	0.6	1.2	8.2	2.8	1.0	0.4	2.2	0.6
AL	36	2nd	1.4	7.0	0.0	0.0	0.8	4.6	1.0	1.0	2.0	4.8	3.0	1.6	0.0	0.0	0.8
AL	36	3rd	0.8	3.0	0.8	0.0	0.2	1.6	1.8	0.0	2.2	4.4	1.0	0.0	0.6	0.0	0.8
AL	36	4th	0.6	5.6	0.6	0.0	0.8	3.2	0.2	0.2	1.0	1.2	3.4	0.4	0.2	0.6	1.6
AL	36	5th	0.0	5.6	0.0	0.4	3.4	0.0	0.8	0.2	0.0	1.0	0.2	0.0	0.0	1.0	0.8
AL	37	1st	0.4	5.4	0.0	0.0	0.0	7.2	0.8	0.0	1.0	10.8	5.6	0.0	0.8	0.0	0.0
AL	37	2nd	0.0	7.8	0.0	0.0	1.0	6.8	2.2	0.0	1.8	4.2	2.6	0.0	0.4	0.0	0.0
AL	37	3rd	0.0	12.6	0.0	1.0	0.4	3.4	0.6	0.0	0.8	3.8	2.8	0.0	0.6	0.0	0.0
AL	37	4th	0.0	10.6	0.2	0.8	1.4	4.6	0.2	0.0	0.4	3.8	1.0	0.0	0.0	0.0	0.0
AL	37	5th	0.0	12.0	0.0	1.4	1.0	4.6	0.2	0.0	0.8	0.6	0.4	0.0	0.0	0.2	0.0
AL	38	1st	0.0	6.7	0.0	0.3	3.7	7.7	0.7	0.7	0.3	5.0	5.3	1.0	0.0	0.0	0.0
AL	38	2nd	0.0	13.0	0.0	1.3	4.7	2.7	0.0	1.3	0.7	3.0	3.0	0.0	0.3	1.3	6.7
AL	38	3rd	1.7	4.3	0.0	0.0	0.0	2.7	3.0	1.3	0.0	2.3	2.0	0.3	1.7	0.0	0.7
AL	38	4th	0.3	3.0	0.0	0.0	0.7	6.7	0.0	0.7	0.3	0.3	2.7	0.3	1.7	0.3	1.0
AL	38	5th	0.0	5.3	0.0	0.0	1.0	0.3	0.0	0.0	0.3	0.0	0.7	0.0	0.0	0.0	1.0
AL	41	1st	0.0	4.8	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
AL	41	2nd	0.0	3.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.5
AL	41	3rd	0.0	4.0	0.0	0.0	1.5	1.0	0.0	0.0	0.3	0.5	0.8	0.0	0.5	0.5	0.5
AL	41	4th	0.0	2.8	0.0	0.0	0.0	5.3	0.0	0.0	0.5	1.5	2.5	0.0	2.5	0.3	1.0
AL	41	5th	0.0	1.0	0.0	0.0	2.3	0.0	0.0	0.0	0.8	0.3	1.5	0.0	2.3	1.8	0.3
AL	43	1st	0.2	4.0	0.4	0.0	3.0	0.8	2.8	1.0	0.0	6.0	3.0	0.6	1.4	0.0	1.8
AL	43	2nd	0.2	7.0	0.8	0.8	2.4	2.6	3.2	0.2	0.2	3.4	4.8	1.2	0.2	0.0	5.0
AL	43	3rd	1.4	5.0	0.8	1.2	2.0	0.8	1.6	0.4	0.2	1.6	2.6	0.8	0.2	0.0	2.6
AL	43	4th	1.2	1.4	1.6	0.4	0.0	3.6	1.8	0.6	0.8	1.2	2.4	1.8	0.6	0.0	4.2
AL	43	5th	4.4	0.6	0.2	0.0	0.2	1.8	1.0	0.4	1.0	1.4	1.2	1.2	0.2	0.0	1.8
AL	44	1st	0.0	2.2	0.4	0.0	0.4	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	2.4
AL	44	2nd	0.0	3.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
AL	44	3rd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
AL	44	4th	0.0	0.4	0.6	0.0	0.0	0.2	0.2	0.0	0.0	0.8	0.0	0.0	0.0	0.0	2.8
AL	44	5th	0.0	1.8	1.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8
AL	4	1st	0.0	19.0	1.0	0.0	0.7	0.3	1.7	0.0	0.0	3.0	1.7	0.0	0.0	0.0	0.3
AL	4	2nd	0.0	11.7	2.3	1.0	0.7	1.7	1.0	0.0	0.3	1.0	2.7	0.0	0.0	0.0	0.3
AL	4	3rd	0.0	13.3	3.7	1.7	2.0	0.0	1.0	0.0	0.0	0.3	0.7	0.0	0.0	0.0	1.3
AL	4	4th	0.0	10.7	3.3	2.7	0.7	0.0	0.3	0.0	0.3	0.7	2.0	0.0	0.0	0.0	0.3
AL	4	5th	0.0	5.0	3.0	0.3	0.3	1.7	0.3	0.0	0.3	1.0	0.3	1.0	2.3	0.0	0.7
AL	5	1st	1.2	8.0	0.2	0.0	0.2	2.0	1.4	0.0	0.0	2.2	0.8	0.4	0.0	0.0	0.0
AL	5	2nd	0.0	8.0	2.8	1.2	1.6	0.0	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	2.0
AL	5	3rd	0.0	4.2	2.4	1.0	1.2	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.2
AL	5	4th	0.8	3.2	2.2	1.6	0.8	1.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.0
AL	5	5th	0.2	4.4	0.6	0.0	0.2	0.2	0.2	0.0	0.0	0.4	0.0	0.0	1.4	0.0	1.2
AL	6	1st	0.0	9.6	7.6	1.2	0.4	0.6	1.0	0.0	0.0	3.4	2.8	0.0	0.0	0.2	1.2
AL	6	2nd	0.2	9.6	5.2	1.0	1.4	0.4	0.2	0.0	0.0	1.8	3.2	0.0	0.0	0.0	2.4
AL	6	3rd	0.0	6.2	5.8	0.0	1.2	0.2	0.6	0.0	0.0	1.0	2.0	0.0	0.0	0.0	1.4

Table A2. (cont'd) Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
AL	6	4th	0.0	2.6	5.6	0.0	0.6	0.2	0.2	0.0	0.0	0.8	0.6	0.0	0.0	0.4	1.2
AL	6	5th	0.0	3.2	0.2	0.0	0.4	0.2	1.0	0.0	0.0	4.8	3.4	0.0	0.0	6.2	0.6
AL	7	1st	0.3	3.3	4.0	0.0	0.8	5.0	0.0	0.5	0.0	1.3	5.5	0.0	0.0	0.0	3.5
AL	7	2nd	0.5	5.8	4.8	0.0	1.5	1.5	0.0	0.5	0.0	1.0	4.5	0.8	0.0	0.0	1.5
AL	7	3rd	0.5	7.8	4.8	0.3	0.8	1.5	0.0	0.3	0.0	0.0	2.5	0.0	0.0	0.0	1.5
AL	7	4th	0.3	4.5	4.8	0.5	0.8	0.3	0.3	0.0	0.0	1.3	3.8	0.0	0.0	0.0	1.5
AL	7	5th	2.5	1.8	6.8	0.0	0.3	1.3	0.0	0.0	0.0	0.3	2.5	0.0	0.0	0.0	1.3
AL	8	1st	0.0	12.2	3.2	0.0	3.2	0.0	0.2	0.0	0.0	2.8	2.4	0.0	0.4	0.0	1.0
AL	8	2nd	0.0	12.0	2.8	0.0	1.2	0.4	0.4	0.0	0.0	3.8	2.0	0.0	0.2	0.0	3.0
AL	8	3rd	0.0	2.2	0.8	0.0	1.6	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.6	0.0	0.8
AL	8	4th	0.0	9.8	2.4	0.0	0.8	0.0	0.4	0.0	0.0	2.4	1.6	0.0	0.2	0.0	4.8
AL	8	5th	4.8	11.6	4.6	0.4	0.2	1.4	2.6	0.0	0.2	1.4	1.6	0.8	0.0	0.0	2.4
AL	9	1st	0.0	8.4	11.0	0.0	2.0	0.4	0.2	0.0	0.0	5.6	0.6	0.2	0.0	0.0	1.2
AL	9	2nd	0.6	6.2	7.4	0.4	1.2	0.8	0.6	0.0	0.0	2.6	0.4	0.0	0.0	0.0	2.4
AL	9	3rd	0.0	5.6	10.0	0.0	0.8	0.6	0.0	0.0	0.0	1.6	0.4	0.0	0.0	0.0	3.6
AL	9	4th	1.4	3.4	7.0	0.2	0.6	2.6	0.6	0.0	0.4	1.0	0.6	0.2	0.0	0.0	5.4
AL	9	5th	0.0	1.2	2.2	0.4	0.6	0.2	1.0	0.0	0.2	2.6	1.2	0.8	0.0	0.0	2.0
FL	1	1st	0.0	17.6	0.0	1.2	3.0	1.2	0.0	0.0	0.0	0.6	3.0	0.0	1.2	0.0	0.0
FL	1	2nd	0.0	15.2	0.0	5.6	2.2	0.4	0.0	0.0	0.0	0.8	4.2	0.0	0.8	0.0	0.0
FL	1	3rd	0.2	9.0	0.0	0.6	0.6	5.4	0.0	0.0	0.6	0.4	1.8	0.2	0.6	1.8	0.2
FL	1	4th	0.0	3.8	0.0	0.4	0.2	5.6	0.0	0.2	0.0	1.6	2.4	0.2	0.0	1.2	1.2
FL	1	5th	0.0	10.8	0.0	1.6	2.0	0.2	0.0	0.0	0.0	0.8	0.8	0.0	1.2	0.0	0.4
FL	2	1st	0.0	1.4	0.0	0.0	0.2	1.6	0.2	0.0	0.0	0.2	0.0	0.0	0.4	0.0	1.6
FL	2	2nd	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2
FL	2	3rd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FL	2	4th	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
FL	2	5th	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FL	3	1st	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.2	0.0	1.6	3.0	0.0	0.0	1.2	0.0
FL	3	2nd	0.0	7.2	0.0	0.0	0.8	0.4	0.0	0.0	0.2	0.2	2.4	0.0	0.2	0.0	0.0
FL	3	3rd	0.0	8.8	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.2	2.6	0.0	0.0	0.0	1.2
FL	3	4th	0.0	3.8	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.2	1.0	0.0	0.0	1.0	0.0
FL	3	5th	0.0	3.6	0.0	1.0	1.0	1.2	0.0	0.0	0.4	0.2	2.0	0.0	0.4	0.4	1.8
FL	4	1st	0.0	10.0	0.0	0.4	1.0	0.0	0.0	0.0	0.0	1.0	2.4	0.0	0.0	0.2	0.2
FL	4	2nd	0.0	12.0	0.0	1.0	1.6	0.4	0.2	0.4	0.2	0.0	1.2	0.0	0.4	0.2	1.2
FL	4	3rd	0.0	9.8	0.0	1.2	0.2	0.2	0.0	0.2	0.2	0.0	1.4	0.0	1.0	0.6	0.2
FL	4	4th	0.0	3.2	0.0	0.0	0.2	1.8	0.2	0.2	1.0	0.2	0.8	0.0	0.2	0.2	0.6
FL	4	5th	0.0	1.8	0.0	0.0	0.0	1.2	0.0	0.4	0.4	0.0	0.4	0.0	1.2	0.8	0.8
FL	5	1st	0.0	3.4	0.0	0.0	0.0	2.2	0.0	0.0	0.4	0.0	0.8	0.0	0.4	0.6	0.0
FL	5	2nd	0.0	3.0	0.0	0.0	1.6	3.6	0.0	0.0	2.0	0.0	2.0	0.0	0.8	8.6	0.0
FL	5	3rd	0.0	8.0	0.0	0.2	1.0	1.0	0.4	0.0	0.0	1.0	2.8	0.0	1.4	4.2	0.2
FL	5	4th	0.0	4.0	0.0	0.0	1.0	1.4	0.2	0.2	1.6	0.2	1.4	0.0	2.6	2.0	0.4
FL	5	5th	0.0	4.0	0.0	0.4	2.2	1.6	0.2	0.0	0.0	0.0	0.8	0.0	0.6	1.0	0.8
FL	6	1st	0.0	12.4	2.4	0.0	4.6	1.0	0.0	1.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0
FL	6	2nd	0.4	11.6	0.6	0.2	2.8	3.8	0.6	0.8	0.4	0.4	1.4	0.0	0.2	0.2	0.2
FL	6	3rd	0.2	12.0	4.0	1.2	4.4	1.2	1.0	0.6	0.4	0.2	0.2	0.0	0.0	0.0	1.8
FL	6	4th	0.0	8.0	2.0	0.6	4.0	2.4	0.4	1.0	0.4	0.0	0.0	0.0	0.6	0.2	0.6
FL	6	5th	0.8	10.8	2.8	0.0	1.0	1.6	2.0	1.2	1.0	0.2	0.6	0.6	0.0	0.2	0.0
FL	7	1st	0.0	5.6	0.0	0.0	0.2	3.6	0.2	0.2	0.6	1.6	1.0	0.0	0.0	2.0	0.6
FL	7	2nd	0.6	9.0	0.0	0.2	1.8	2.4	0.0	0.0	0.0	0.4	1.8	0.0	0.8	0.4	0.0
FL	7	3rd	0.8	6.8	0.0	0.4	0.8	5.4	0.0	0.0	1.4	0.6	1.0	0.0	0.0	0.0	1.0

Table A2. (cont'd) Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
FL	7	4th	0.0	5.6	0.0	1.0	0.4	4.2	0.6	0.6	1.8	0.8	2.0	0.0	0.2	1.2	0.2
FL	7	5th	0.0	10.8	0.0	3.6	2.0	1.8	0.6	0.2	0.2	0.6	3.2	0.0	2.4	2.4	0.6
FL	8	1st	0.0	8.3	0.0	1.3	4.8	0.3	0.0	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.5
FL	8	2nd	0.0	10.3	0.0	1.0	4.0	0.8	0.0	0.0	0.3	0.0	1.3	0.0	0.0	1.3	0.8
FL	8	3rd	0.0	2.0	0.3	0.0	0.3	3.5	0.0	0.0	1.3	0.0	0.8	0.0	0.0	3.0	0.3
FL	8	4th	0.0	2.0	0.8	0.3	0.3	1.8	0.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0
FL	8	5th	0.0	6.5	0.8	0.8	1.3	2.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.3
FL	9	1st	0.0	0.2	0.0	0.0	0.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.2
FL	9	2nd	0.0	3.2	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.2	0.0	1.0	0.4	0.8
FL	9	3rd	0.0	0.4	0.0	0.0	0.4	4.4	0.0	0.0	0.8	0.0	0.0	0.2	0.0	0.4	1.6
FL	9	4th	0.0	1.0	0.0	0.0	0.6	6.0	0.0	0.0	0.6	0.0	1.6	0.0	0.8	1.4	3.2
FL	9	5th	0.0	0.2	0.0	0.0	0.4	9.2	0.0	0.0	2.6	0.0	0.6	0.2	0.2	5.0	1.4
GA	10	1st	0.0	10.0	1.2	0.6	5.8	0.0	0.2	0.0	0.0	2.0	0.2	0.0	0.4	0.2	0.4
GA	10	2nd	0.2	12.8	2.0	0.2	4.2	2.2	0.4	0.2	2.0	1.2	1.4	1.4	2.4	1.4	2.6
GA	10	3rd	0.0	10.8	1.6	0.0	3.8	1.2	0.2	0.0	0.6	2.4	1.0	0.8	0.6	2.2	2.6
GA	10	4th	0.6	12.8	2.4	0.6	3.6	0.8	0.0	0.2	0.6	1.6	2.0	0.4	1.2	0.4	2.6
GA	10	5th	0.2	9.0	1.0	1.2	5.0	0.6	0.4	0.2	0.4	1.0	2.0	0.4	0.0	0.4	2.2
GA	16	1st	0.0	9.7	2.0	0.0	1.0	2.3	1.0	0.0	0.3	5.7	2.0	1.7	0.3	0.0	0.0
GA	16	2nd	0.0	12.7	1.3	0.0	4.3	0.0	1.0	0.0	0.0	0.0	0.3	0.7	0.0	0.0	0.0
GA	16	3rd	0.3	13.0	1.7	2.0	3.0	0.3	0.3	0.0	0.0	1.0	1.0	0.0	0.7	0.0	0.0
GA	16	4th	0.3	11.0	0.7	1.0	2.7	1.0	0.3	0.0	0.0	0.7	1.0	0.0	0.7	0.0	0.0
GA	16	5th	0.0	9.7	4.3	0.3	3.3	0.7	0.7	0.0	0.0	2.3	0.0	0.0	3.3	0.0	1.3
GA	22	1st	0.3	12.7	2.3	0.7	2.3	1.3	0.7	0.0	0.3	2.7	5.7	0.0	2.7	0.3	1.3
GA	22	2nd	1.0	11.7	2.0	1.0	4.7	0.3	0.3	0.0	0.0	2.7	1.0	0.3	1.3	0.0	0.3
GA	22	3rd	2.0	10.0	0.7	0.7	1.7	1.7	1.0	0.0	0.0	0.7	2.0	0.7	0.0	0.0	0.3
GA	22	4th	2.7	10.7	3.3	0.3	0.7	0.3	0.7	0.0	0.0	0.7	1.3	0.3	0.0	0.0	0.7
GA	22	5th	0.7	8.7	0.0	0.3	1.0	1.0	1.0	0.3	0.3	1.0	0.3	0.3	0.0	0.0	2.0
GA	25	1st	0.0	10.3	0.3	1.8	5.0	0.3	0.0	0.0	0.0	0.3	1.5	0.0	0.0	0.3	0.5
GA	25	2nd	0.0	12.0	0.0	2.8	2.8	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.0
GA	25	3rd	0.0	13.0	0.3	5.8	3.0	0.5	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
GA	25	4th	0.0	8.8	0.3	4.5	2.8	0.3	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
GA	25	5th	0.0	10.8	0.8	1.3	3.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.5
GA	26	1st	0.0	5.4	2.2	0.0	0.2	1.8	1.2	0.6	0.0	4.2	0.6	1.6	0.0	0.0	0.6
GA	26	2nd	0.6	6.6	4.4	0.0	1.4	0.6	2.4	0.4	0.0	3.6	0.8	0.2	0.2	0.2	3.6
GA	26	3rd	0.0	5.6	2.4	0.2	0.8	0.4	1.0	0.0	0.0	1.4	0.6	0.0	1.0	0.0	1.0
GA	26	4th	0.0	3.8	2.6	0.0	0.6	0.0	1.2	0.4	0.0	0.8	0.0	0.2	0.6	0.2	1.0
GA	26	5th	0.8	7.4	6.2	0.6	0.4	1.0	2.0	0.0	0.0	1.4	0.4	0.2	0.8	0.0	2.0
GA	28	1st	0.3	7.5	2.3	0.3	2.8	1.0	0.5	0.0	0.3	4.8	2.0	1.0	0.0	0.0	1.5
GA	28	2nd	0.0	10.5	4.0	0.0	2.8	0.5	0.3	0.0	0.5	3.8	3.8	1.0	0.5	0.0	0.5
GA	28	3rd	0.0	10.3	0.3	0.0	2.5	0.8	0.5	0.8	0.0	2.3	2.5	0.3	0.3	0.0	2.8
GA	28	4th	0.0	9.5	3.0	0.3	3.8	0.0	0.0	0.0	0.0	1.8	3.0	0.0	1.3	0.0	0.0
GA	28	5th	1.8	10.5	5.8	0.8	4.0	1.3	1.0	0.3	0.5	3.0	2.8	1.0	1.3	1.0	4.0
GA	33	1st	0.0	19.3	3.3	3.7	3.7	0.3	0.3	0.0	0.0	2.3	3.0	1.3	0.3	0.3	0.0
GA	33	2nd	0.0	14.3	1.3	1.0	0.7	1.0	0.0	0.0	0.3	0.0	1.3	0.0	1.0	0.0	1.0
GA	33	3rd	0.0	9.3	1.0	1.7	3.3	0.0	0.3	0.0	0.3	1.3	0.7	0.0	1.3	0.0	1.7
GA	33	4th	0.0	6.0	1.3	2.7	2.0	2.0	1.0	0.3	0.0	1.0	1.7	0.0	0.7	1.0	5.0
GA	33	5th	0.0	8.7	1.3	2.3	2.0	1.3	0.7	0.0	0.3	3.7	2.0	1.3	0.7	1.3	1.0
GA	36	1st	0.0	7.3	0.3	0.3	0.7	1.0	1.0	0.0	0.3	4.3	0.0	0.3	0.0	0.0	0.0
GA	36	2nd	3.3	14.0	2.3	0.7	0.0	0.7	1.0	0.0	0.0	2.0	2.3	0.7	0.0	0.0	1.0
GA	36	3rd	2.0	5.7	3.3	1.3	1.3	0.0	0.7	0.0	0.0	2.0	0.3	0.0	0.3	0.0	4.3

Table A2. (cont'd) Mean yearly abundance for each species for each of the 265 partial BBS routes.

State	Rt	Partial	AOU Number														
	#	Rt	6730	2890	5630	6220	4440	6310	4610	6280	6840	7550	3870	6770	7290	6370	4950
GA	36	4th	1.0	7.7	2.3	0.0	1.0	2.3	1.0	0.0	0.0	2.3	2.0	1.7	0.3	0.0	1.3
GA	36	5th	0.0	7.0	1.3	0.0	0.3	0.7	3.0	0.0	0.0	1.3	1.7	0.7	0.3	0.0	1.3
GA	37	1st	0.2	5.4	6.2	0.0	3.8	0.6	3.0	0.4	0.0	5.8	1.0	0.0	0.0	0.0	1.2
GA	37	2nd	1.2	9.0	3.8	0.4	1.2	0.6	2.8	1.0	0.0	1.4	0.4	1.2	0.2	0.0	4.0
GA	37	3rd	0.6	8.8	5.6	0.6	1.2	0.2	2.4	0.8	0.0	2.6	0.6	0.0	0.2	0.0	1.6
GA	37	4th	1.2	6.2	6.8	0.0	0.8	0.0	1.8	0.4	0.0	1.8	0.4	0.4	0.0	0.0	4.0
GA	37	5th	2.2	6.0	4.4	0.2	0.8	0.6	1.2	0.4	0.0	1.8	0.8	0.2	0.0	0.0	2.2
GA	38	1st	0.0	7.2	0.0	0.2	5.4	0.6	0.2	0.0	0.0	6.8	0.8	0.0	0.0	0.0	1.6
GA	38	2nd	0.8	11.8	1.0	0.6	4.4	2.6	0.0	0.0	0.4	5.6	1.6	0.4	0.4	0.8	3.0
GA	38	3rd	2.4	14.8	2.4	1.0	4.0	0.6	0.6	0.2	0.2	1.4	1.6	0.0	1.6	0.0	5.0
GA	38	4th	0.8	11.8	0.4	0.8	3.6	1.0	0.2	0.2	0.6	1.4	0.8	0.2	1.0	0.6	4.8
GA	38	5th	1.4	6.6	1.6	0.6	2.6	1.2	0.4	0.0	0.8	1.2	1.2	0.4	1.0	0.2	4.4
GA	6	1st	0.0	21.8	0.0	1.0	0.6	0.2	0.0	0.0	0.0	2.0	2.6	0.0	0.0	0.0	0.8
GA	6	2nd	0.0	23.8	0.0	1.8	0.8	2.6	0.2	0.0	0.0	0.2	3.6	0.0	0.0	0.8	1.4
GA	6	3rd	0.0	26.6	0.0	2.6	0.4	0.6	0.0	0.0	0.0	1.2	1.0	0.0	0.0	0.0	1.2
GA	6	4th	0.0	13.0	0.2	1.0	1.2	4.4	0.2	0.6	1.0	1.6	3.2	0.2	0.2	1.2	2.8
GA	6	5th	0.0	17.4	1.4	2.4	0.0	2.6	0.0	1.0	0.2	0.2	2.2	0.2	0.0	0.4	1.0

APPENDIX B

CLIMATE DATA ANALYSIS

Methods

The weather conditions during the years of this study (1970 – 1976) were compared to a long-term period of weather record. This was done to determine if the years included in the study were atypical when compared to the long-term period of record. Pertinent weather stations were selected from EarthInfo Environmental Database Summary of the Day CDs. This was done separately for Alabama, Georgia, and Florida and then combined into a comprehensive database. The climate data for the study timeframe were based on weather stations that had data for the years 1970 to 1976 while the long-term climate data were based on weather stations that had a minimum of thirty years of record. For each weather station and timeframe, the following data were obtained directly or were calculated from data on the CD: latitude, longitude, minimum yearly mean temperature in degrees Fahrenheit, and maximum yearly mean temperature in degrees Fahrenheit. The number of weather stations used for the following four scenarios was:

174	minimum yearly mean temperature for long-term period of record
123	minimum yearly mean temperature for the study timeframe
174	maximum yearly mean temperature for long-term period of record
123	maximum yearly mean temperature for the study timeframe

A GIS was used to provide a geographic view of the climate conditions in the study area for the study timeframe and a longer period of climate record. This provided a general geographic overview of the climate conditions of the study timeframe and the longer period of climate record.

Separate GIS coverages were developed for the minimum yearly mean temperature for long-term period of record, minimum yearly mean temperature for the study timeframe, maximum yearly mean temperature for long-term period of record, maximum yearly mean temperature for the study timeframe. All weather stations within each GIS coverage were used to develop a surface model. First, a triangulated irregular network (TIN) was developed. A TIN model is a set of adjacent, non-overlapping triangles computed from irregularly spaced points. Each TIN model was then transformed into a lattice file with a grid cell size of 250 meters. The grid files were used to illustrate the gradation of values in temperature. Also, to show the differences between the two timeframes, the values for the study timeframe were subtracted from those of the long-term period of record for minimum and maximum yearly mean temperature.

Unlike temperature, precipitation is discontinuous in both the geographic and temporal variables. As a result, precipitation data, gathered at a discreet location and over discreet intervals, inherently have much higher degrees of variability. A general snapshot of the precipitation over the study area was developed by creating a 30-year time sequence of total annual precipitation for 3 locations in the study area. Three weather stations, one in the northern, one in the central, and one in the coastal portion of the study area, were used to determine the total annual precipitation in 1/100 of an inch increments for every year of record.

Results and Conclusions

The minimum and maximum yearly mean temperature provide two measurements that give a general indication of the weather conditions of the study area. The geographical numerical differences were primarily between positive or negative 1 to 2 degrees Fahrenheit (Figures B3 and B6). Also, the precipitation time sequence that was developed for three weather stations in the study area did not have visible outliers and appeared to be compatible with the trends of the annual precipitation of the long-term period of record. Therefore, it can be inferred that the results of the overall dissertation study should not be affected by unusual climate conditions in reference to the minimum and maximum yearly mean temperature and annual precipitation. More specific discussion is listed below.

Figures B1 and B2 show the minimum yearly mean temperature for the study timeframe and the long-term period of record, respectively. Figure B3 shows the map of the numerical difference between the mean temperature values for the two timeframes. As shown on Figures B1 and B2, the mean temperature values for the two timeframes range from approximately 44 to 62 degrees Fahrenheit. As would be expected, it is apparent that the lowest temperatures are in the northern portion of the study area with a gradation to higher temperatures in the southern portion of the study area. Figure B3 shows the differences in the two timeframes ranges from -3 to 6 degrees Fahrenheit, but with the majority of the study site varying only about positive or negative 1 to 2 degrees Fahrenheit. When an average of all grid cells depicting the minimum yearly mean

temperature was calculated for the study area, the value was the same for the study timeframe and the long-term period of record.

Figures B4 and B5 show the maximum yearly mean temperature for the study timeframe and the long-term period of record, respectively. Figure B6 shows the map of the numerical difference between the maximum yearly mean temperature values for the two timeframes. Figures B4 and B5 show the maximum yearly mean temperature values for the two timeframes range from about 68 to 82 degrees Fahrenheit. The temperatures are lowest in the north and gradually get higher in the southernmost portion of the study area. Figure B6 shows the differences vary from -2 to 5 degrees Fahrenheit. The majority of the study site varies only about positive 1 to 2 degrees or negative 1 degree Fahrenheit between the two timeframes. When an average of all grid cells depicting the maximum yearly mean temperature was calculated for the study area for the two timeframes, the value was the same for the study timeframe and the long-term period of record.

A plot (Figure B7) was developed to show the annual precipitation for each year of record for the 3 stations. The study timeframe is marked on Figure B7, illustrating the pattern of the study timeframe in comparison to the long-term period of record. It appears from Figure 8 that the annual precipitation during the study timeframe follows the same trends as the long-term period of record and that there are no exceptional values that make the study timeframe unique.

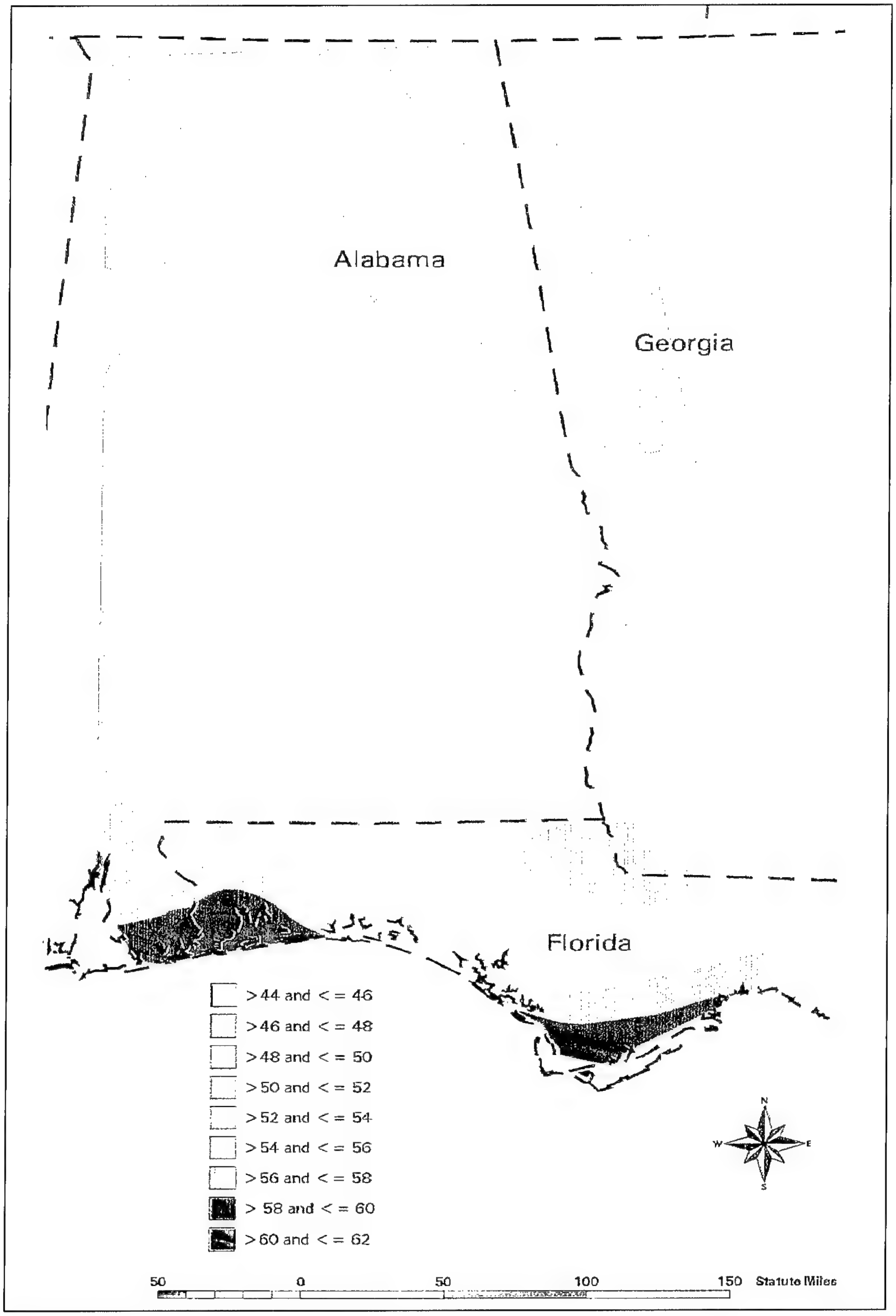

Figure B1. Minimum Yearly Mean Temperature in Degrees Fahrenheit for the Study Time Frame.

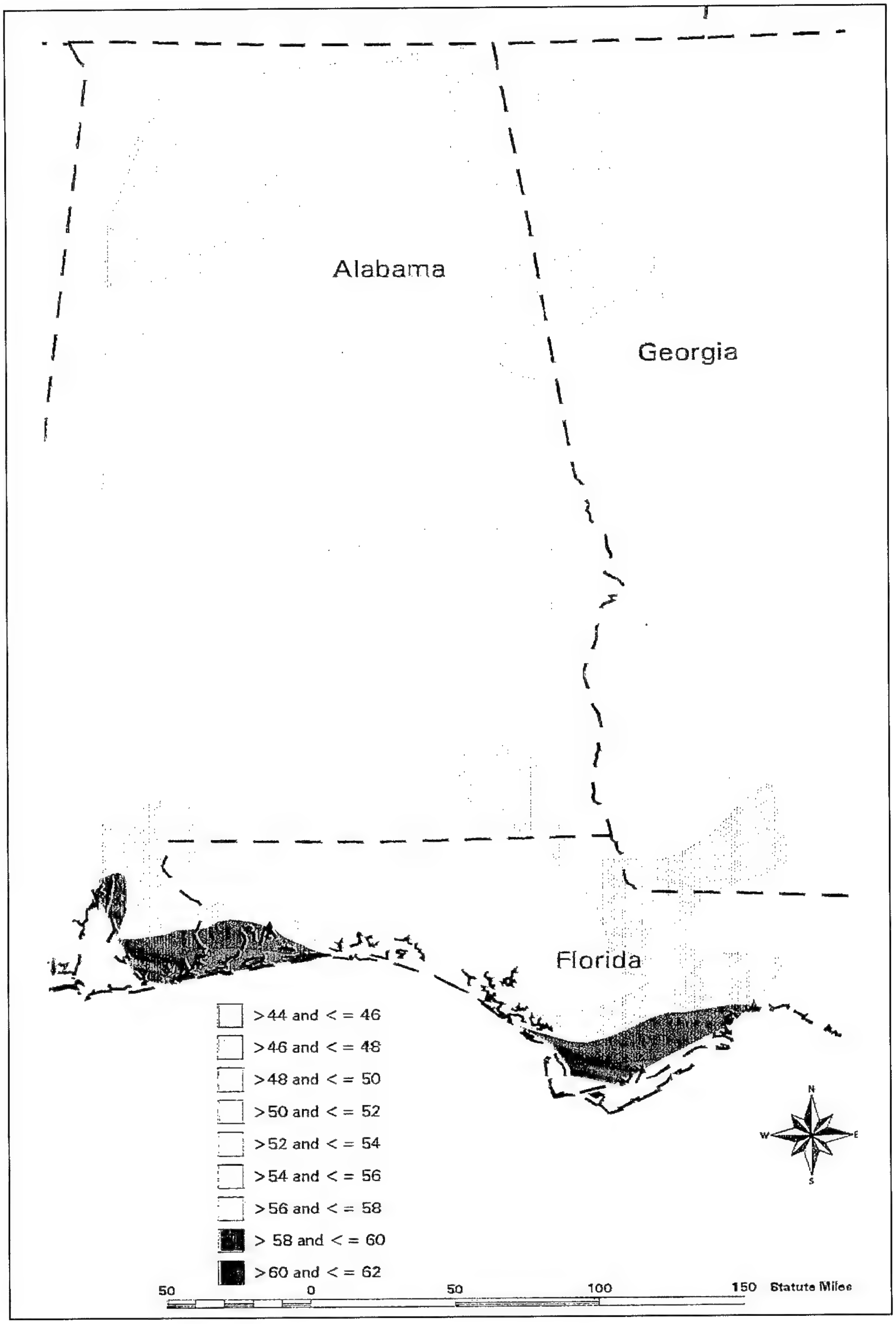

Figure B2. Minimum Yearly Mean Temperature in Degrees Fahrenheit for the Long-term Period of Record.

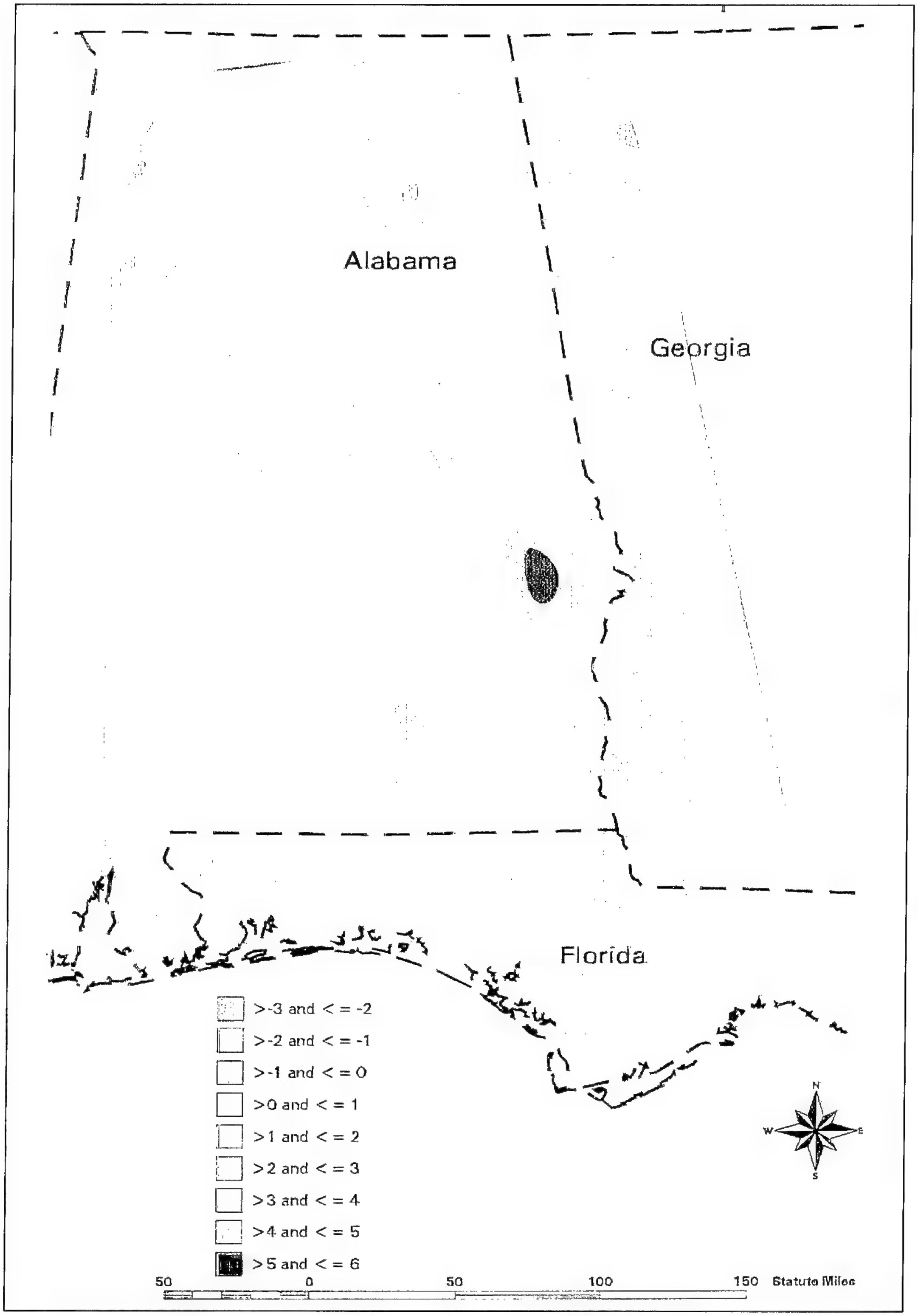

Figure B3. Difference in Minimum Yearly Mean Temperature in Degrees Fahrenheit for the Study Timeframe and the Long-term Period of Record.

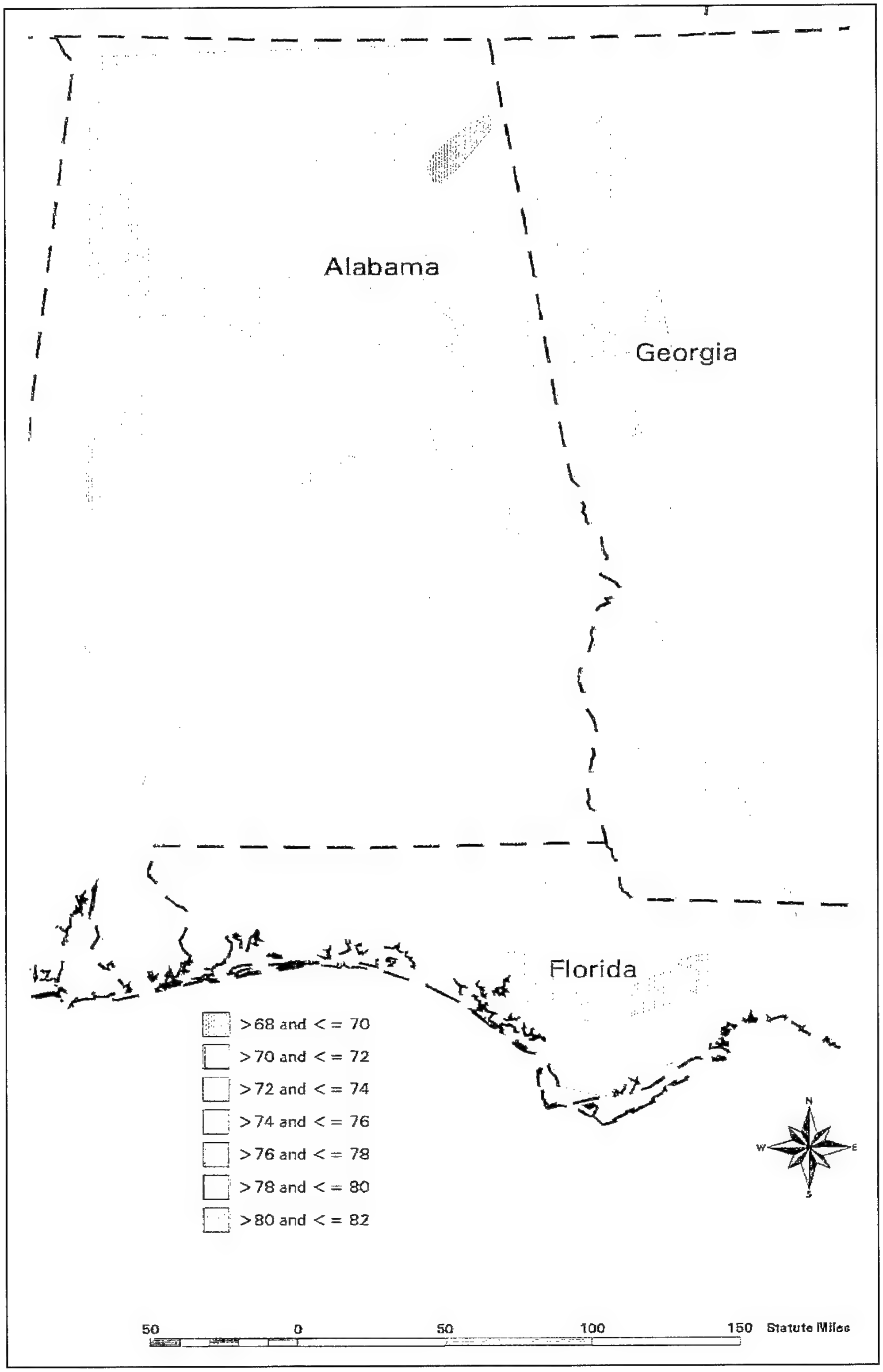

Figure B4. Maximum Yearly Mean Temperature in Degrees Fahrenheit for the Study Timeframe.

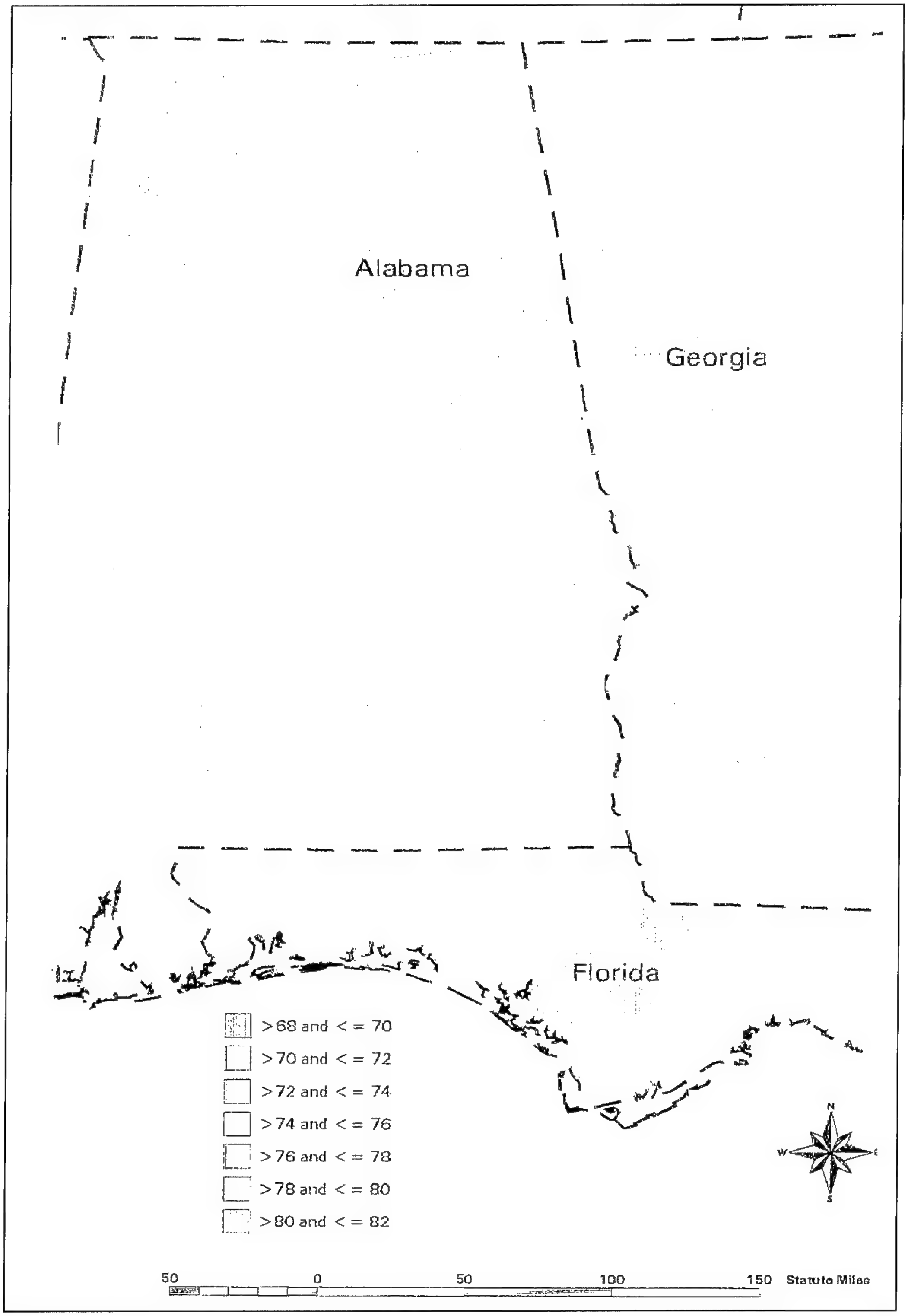

Figure B5. Maximum Yearly Mean Temperature in Degrees Fahrenheit for the Long-term Period of Record.

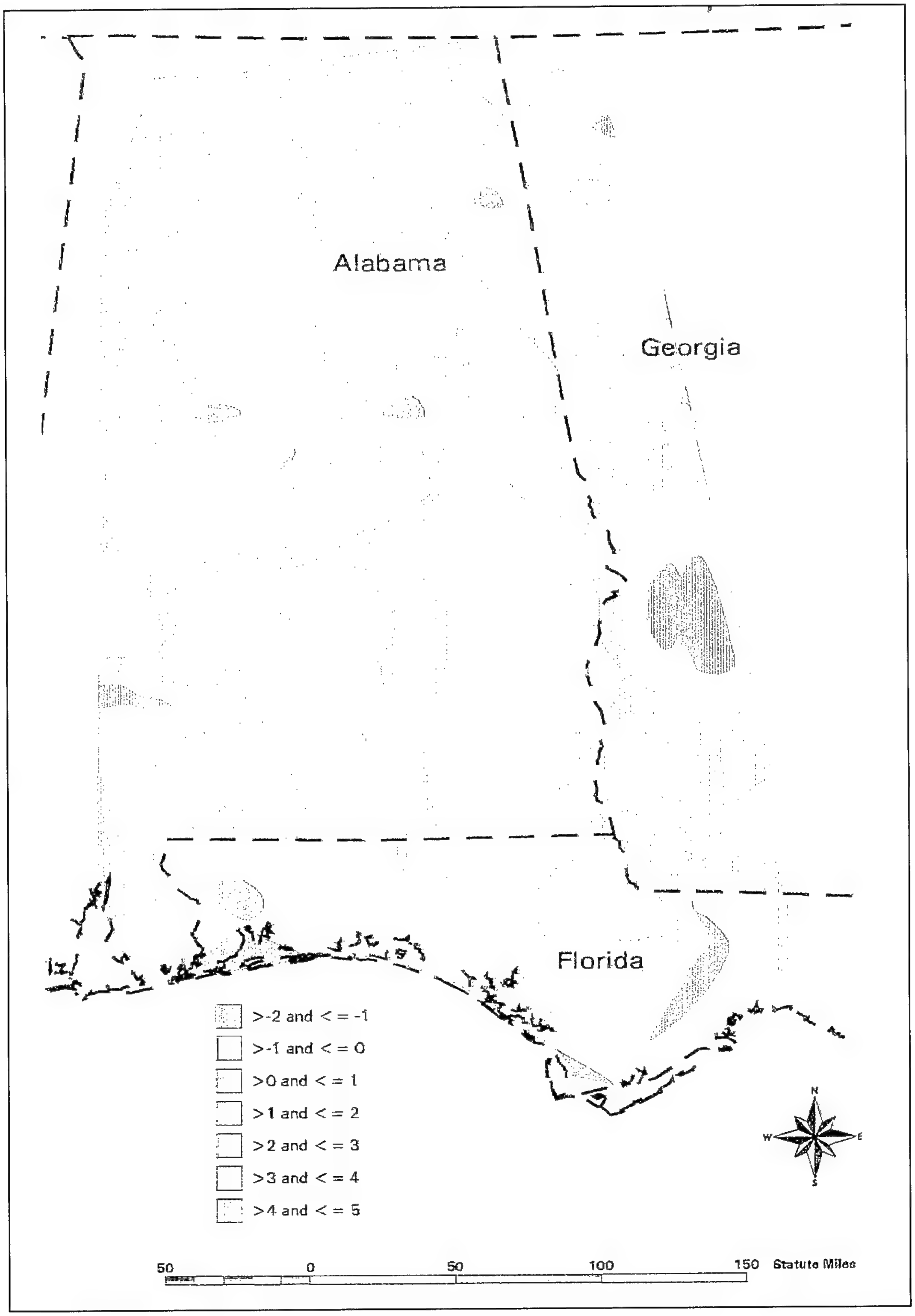

Figure B6. Difference in Maximum Yearly Mean Temperature in Degrees Fahrenheit for the Study Timeframe and the Long-term Period of Record.

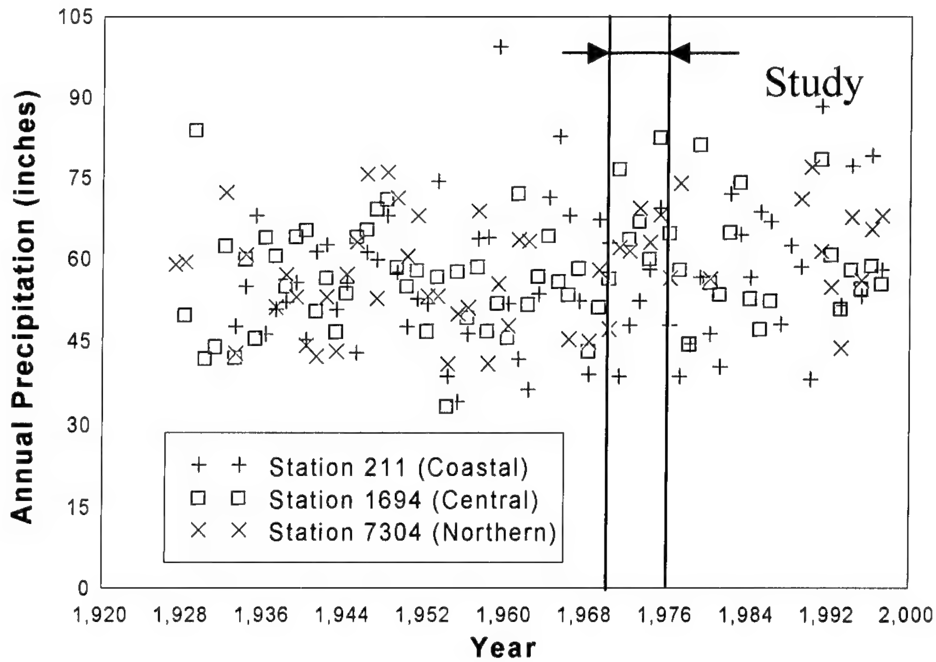

Figure B7. Plot of annual precipitation for each year of record for 3 weather stations.

APPENDIX C

LANDSCAPE SPATIAL PATTERN METRICS

Tables C1-C4 list the value of each of the 12 metrics for each study site for Extent 1-4, respectively. There are some study sites that do not have a value for IJI. This is due to the fact that FRAGSTATS cannot calculate IJI for samples with < 3 distinct patch types.

Table C1. Value of each of the 12 metrics for each study site for Extent 1.

State	Rt #	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	1	54.16	0	2.49	0	32.83	53.84	0.66	14.36	1.54	7.47	0.59	47.14
AL	10	20.97	0	20.56	6.34	49.76	244.82	0.31	11.32	1.9	23.72	0.66	59.12
AL	11	26.58	0	3.66	15.38	51.33	185.69	0.38	11.51	1.86	21.76	0.64	56.02
AL	12	6.46	0	12.81	9.5	67.65	827.93	0.11	4.66	2.78	36.65	0.51	52.97
AL	13	26.71	0	0	22.09	42.52	116.2	0.56	16.62	1.77	16.43	0.7	57.05
AL	15	29.58	0	0	4.04	61.33	138.71	0.47	15.54	1.8	16.82	0.53	34.09
AL	16	39.43	0	0	2.65	52.24	66.42	0.83	15.85	1.46	15.18	0.57	36.28
AL	17	8.82	0	0	0	81.83	369.37	0.22	11.26	2.23	24.37	0.32	54.09
AL	2	52.32	0	0.91	0	45.65	73	0.64	7.49	1.73	26.38	0.52	34.52
AL	22	68.51	0	3.57	0	24.87	39.71	0.72	12.48	1.58	8.54	0.47	36.29
AL	23	20.73	0	0	0	77.25	300.14	0.26	10.22	1.98	25.23	0.36	26.46
AL	24	36.28	0	0	12.91	49.5	136.06	0.46	11.75	1.85	21.66	0.61	38.57
AL	25	47.26	0	0	2.74	47.35	57.24	0.87	16.68	1.71	14.88	0.55	33.36
AL	26	38.91	0.65	0	4.44	52.53	114.91	0.5	17.16	1.92	11.31	0.57	35.51
AL	28	24.83	0	2.94	18.26	47.91	200.65	0.34	11.63	2.26	21.67	0.67	51.65
AL	29	39.62	0	0	0	56.37	159.63	0.35	10.19	1.73	21	0.52	33.82
AL	30	78.43	0	0	0	19.29	13.39	1.44	14.44	1.49	1.03	0.35	28.74
AL	31	73.9	0	0	3.99	19.73	19.83	1.2	15.82	1.4	1.22	0.41	41.71
AL	32	67.92	0	0	0.95	26.01	18.57	1.45	16.81	1.51	3.29	0.47	34.75
AL	34	29.33	0	0	9.24	61.2	163.98	0.43	9.98	1.82	25.51	0.53	45.23
AL	35	15.34	0	0.23	55.08	26.65	531.73	0.15	10.35	2.99	24.03	0.6	52.77
AL	36	20.14	0	0	0.24	73.05	336.09	0.22	5.77	1.96	29.69	0.42	55.89
AL	37	25.24	0	0	2.29	72.26	265.87	0.28	10.49	2.08	23.59	0.41	30.79
AL	38	31.81	0	0	1.21	65.55	211.26	0.32	9.01	1.8	27.23	0.47	32.59
AL	4	46.32	0	0.18	0.93	47.46	57.71	0.84	17.12	1.66	10.45	0.56	37.17
AL	41	0	9.15	0	2.74	24.2	129.91	0.28	9.65	2.32	16.72	0.86	75.68
AL	43	13.74	0	0	0	81.6	289.14	0.28	8.78	2.04	28.37	0.31	41.19
AL	44	0.96	0	0	0	2.42	12.72	0.19	2.11	1.49	0	0.57	58.69
AL	5	62.28	0	0	0.32	32.71	30.41	1.09	14.77	1.56	9.17	0.5	29.55
AL	6	37.51	2.33	4.07	0.56	19.7	47.92	0.56	11.08	1.55	5.06	0.78	59.58
AL	7	63.83	0	0.07	0	31.56	67.29	0.47	11.22	1.7	1.97	0.49	35.7
AL	8	41.65	0	9.55	4.66	27.25	66.35	0.62	11.21	1.53	15.29	0.73	60.65
AL	9	80.59	0	9.17	0.31	8.11	47.17	0.37	6.63	1.48	6.78	0.34	61.17

Table C1. (cont'd) Value of each of the 12 metrics for each study site for Extent 1.

State	Rt #	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
FL	1	20.51	4.35	0	57.99	5.95	121.53	0.56	15.78	2	18.16	0.61	54.48
FL	2	0	3.92	0	22.82	0	45.81	0.58	10.72	1.74	13.3	0.83	70.65
FL	3	4.51	1.92	0	72.98	4.78	328.17	0.24	8.58	2	27.17	0.46	68.78
FL	4	30.34	5.82	0	59.34	2.5	145.03	0.47	15.4	1.98	17.13	0.55	46.76
FL	5	9.89	8.28	0	72.33	2.98	535.52	0.16	0	2.47	26.41	0.46	59.42
FL	6	25.06	0.58	0	62.43	1.25	120.54	0.53	19.61	1.95	12.36	0.54	43.05
FL	7	10.53	8.21	0.68	39.64	36.11	272.37	0.31	11.62	1.99	25.37	0.69	55.6
FL	8	18.1	5.39	0	59.57	14.72	212.12	0.38	11.56	1.89	27.97	0.59	53.49
FL	9	0	0.4	0	74.86	3.9	841.52	0.09	14.13	2.81	21.55	0.43	57.91
GA	10	67.1	7.34	6.31	8.52	4.57	42.58	0.63	11.75	1.51	9.27	0.53	51.42
GA	16	31.09	0.55	4.5	6.87	54.41	123.36	0.54	12.49	1.92	20.43	0.6	45.32
GA	22	54.66	3.45	3.94	0.8	31.47	40.46	0.98	17.33	1.6	8.06	0.6	49.08
GA	25	68.54	1.03	8.94	11.57	3.17	33	0.75	12.37	1.52	5.26	0.51	50.33
GA	26	33.68	0	10.76	10.84	35.37	139.8	0.41	10.68	1.79	20.43	0.73	58.65
GA	28	71.08	0	0	15.01	12.88	49.88	0.56	10.69	1.5	9.4	0.46	47.29
GA	33	52.2	1.83	6.83	9.37	13.65	47.98	0.66	10.46	1.49	11.77	0.68	57.93
GA	36	30.77	0	14	8.18	38.88	91.33	0.67	18.51	1.62	12.31	0.72	62.99
GA	37	27.84	0	10.34	16.41	44.15	251.48	0.28	11.61	2.37	17.86	0.69	57.82
GA	38	26.01	2.87	0.64	25.73	40.37	186.1	0.37	11.61	1.74	21.86	0.7	55.2
GA	6	61.87	0	6.65	13.06	16.17	44.29	0.81	13.28	1.49	10.85	0.57	51.3

Table C2. Value of each of the 12 metrics for each study site for Extent 2.

State	Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#						(ha)	(no/	(m/ha)		(%)		(%)
								100 ha)					
AL	1	38.2	0.57	9.8	1.13	36.2	426.4	0.11	11.3	1.62	50.6	0.71	43.6
AL	10	12	0	26.8	13.4	45.3	8151	0.01	5.92	1.88	79.9	0.69	39.5
AL	11	20.8	0	5.26	6.16	58.6	1696	0.04	8.45	1.67	70.6	0.6	49.5
AL	12	12.6	0	16.6	9.95	55.3	3233	0.03	5.81	1.88	81.1	0.64	50.7
AL	13	15.6	0	0.74	11.6	62.3	3792	0.02	9.58	2.42	67.1	0.57	47.1
AL	15	18.1	0	0	0.74	74.2	5642	0.01	12.6	2.42	57.1	0.42	33.7
AL	16	18.1	0	0	2.61	77.6	11113	0.01	9.2	2.65	68.1	0.36	21.5
AL	17	3.81	0	0	2.78	78.6	8136	0.01	9.18	2.34	69	0.37	51.8
AL	2	63.9	0.07	2.54	0.39	28.5	205.7	0.15	9.95	1.43	35.6	0.51	27.4
AL	22	43.5	1.98	3.1	5.31	41.3	1057	0.05	11.8	1.69	47.2	0.64	41.4
AL	23	9.2	0.02	1.59	0.42	87.3	17433	0.01	5.2	2.24	81.7	0.23	25.7
AL	24	41	0.19	1.08	6.95	50	809.7	0.07	11.9	1.67	51.9	0.58	24.5
AL	25	21.3	0.11	1.16	2.25	70.6	1898	0.04	12.6	1.96	58.3	0.45	30.3
AL	26	37.9	1.49	1.5	1.3	50.3	606.2	0.09	14.4	1.87	43	0.6	41.4
AL	28	20.9	0.18	4.72	12.6	53.6	1614	0.04	11.7	1.76	58.9	0.65	48.8
AL	29	24.6	0	1.12	3.07	69.3	3825	0.02	8	1.8	69.8	0.46	31.7
AL	30	50.3	0.52	0.15	1.28	45.3	620.3	0.08	16.4	1.95	29	0.54	19.1
AL	31	56.1	1.87	2.09	6.39	30.8	81.45	0.17	7.7	1.51	13	0.59	32.1
AL	32	34.1	2.87	0.01	3.57	57.6	2063	0.03	16.5	2.05	42	0.55	23.9
AL	34	23.8	1.12	0.33	15.8	57.6	3026	0.02	8.79	1.72	69.6	0.59	28.3
AL	35	11.8	2.85	0.06	50.8	31.3	10576	0.01	7.69	2.25	74.2	0.63	41.6
AL	36	18.2	0.21	0.52	5.04	71.6	4056	0.02	7.6	1.89	72.7	0.45	36.6
AL	37	8.79	21.6	0	8.02	57.2	9166	0.01	6.39	2.14	78.5	0.61	47
AL	38	22.6	0.03	0	19.1	55.4	2919	0.03	8.94	1.79	69.3	0.61	37.5
AL	4	31.7	0.05	1.37	2.33	57.8	998.4	0.06	13.2	1.64	48.1	0.56	31.6
AL	41	5.36	1.46	0.02	4.5	7.25	398.5	0.03	4.14	1.81	38.8	0.48	69.1
AL	43	5.09	0	0.35	1.23	86.1	20702	0	6.99	3.26	76.6	0.25	45.4
AL	44	4.45	0.13	0.51	0.89	51.6	1884	0.03	9.69	2.07	55.2	0.64	56.3
AL	5	44.9	0	0.04	0.36	53.5	495.9	0.11	16	1.65	36.6	0.51	13.4
AL	6	40.4	1.4	3.07	1.27	35.5	422.8	0.1	11.6	1.55	36.5	0.7	50.1
AL	7	30.4	0.04	39.5	0.22	29.2	1676	0.04	6.6	1.47	74.9	0.67	29.9
AL	8	30	1.54	11.2	5.57	41.3	1560	0.04	8.45	1.7	63.5	0.72	45.6
AL	9	60.9	0	12.6	1.35	17.7	276.7	0.11	9.45	1.56	38.5	0.58	41.5

Table C2. (cont'd) Value of each of the 12 metrics for each study site for Extent 2.

State	Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#						(ha)	(no/ 100 ha)	(m/ha)		(%)		(%)
FL	1	20.7	12.5	0.1	54.7	7.62	2184	0.03	9.66	1.66	69.5	0.64	39.3
FL	2	0.08	5.84	0.05	14.8	1.01	798.8	0.03	3.17	1.65	66	0.52	66
FL	3	8.04	2.35	0.06	63.1	12.1	5006	0.02	5.99	2.23	80.3	0.58	52.5
FL	4	17.2	21	0	55.8	2.04	2920	0.03	9.35	1.9	70.9	0.61	39.4
FL	5	2.78	14.5	0	73.7	4.87	30511	0	3.3	2.43	88	0.43	33.4
FL	6	25.2	2.54	0	52.4	4.69	997	0.06	16.7	1.91	42.4	0.65	43.1
FL	7	8.59	22.5	0.04	41.5	25.3	5666	0.02	6.82	2.07	79.3	0.71	45.2
FL	8	4.44	20	0	57.1	15.2	11156	0.01	5.12	2.17	84	0.61	40.1
FL	9	0.02	7.61	0	24	10.2	3470	0.01	4.35	2.28	76.4	0.69	56.7
GA	10	55.2	8.15	13.5	11.2	9.47	345.4	0.12	14	1.63	31.9	0.65	44.2
GA	16	29	0.14	9.9	10.9	45.5	2180	0.03	10.8	1.7	59.7	0.69	45.6
GA	22	37.2	1.74	12.1	6.19	36.4	856	0.07	16.6	1.78	36	0.71	50.3
GA	25	63.6	4.26	5.5	17.8	6.41	174	0.19	14.6	1.64	21.5	0.55	40.9
GA	26	26.2	0	22.7	14.3	32.6	2307	0.03	7.69	1.75	70.5	0.75	51.4
GA	28	60.1	1.94	0.08	19.6	14.2	359.7	0.1	11.3	1.69	34.8	0.58	38
GA	33	48.9	4.58	10.4	7.22	24.2	104	0.09	4.38	1.35	21	0.68	47.9
GA	36	25.7	0.06	11.9	8.47	51.8	1390	0.05	13.4	1.86	57	0.64	40.4
GA	37	21.9	0	16.3	10	49.1	4618	0.02	7.16	1.79	73.1	0.67	42.6
GA	38	20.7	4.36	1.25	28.3	43.8	5593	0.01	8.59	1.83	68.7	0.68	43.4
GA	6	35.5	0.07	4.14	31.3	24.6	1128	0.05	11.9	1.58	52.8	0.71	44.4

Table C3. Value of each of the 12 metrics for each study site for Extent 3.

State	Rt #	Partial Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	10	1st	40.04	0	11.61	0	43.27	75.26	0.73	20.09	1.8	5.62	0.64	53.29
AL	10	2nd	4.33	0	23.24	17.86	54.57	641.08	0.15	4.23	2.21	33.11	0.61	64.62
AL	10	3rd	9.86	0	33.16	0	56.98	615.82	0.15	6.75	2.31	27.33	0.56	82.16
AL	10	4th	44.02	0	25.95	0	30.03	62.95	0.89	16.92	1.54	8.28	0.65	91.14
AL	10	5th	4.81	0	15.05	12.13	62	608.78	0.15	8.64	2.66	26.1	0.57	60.19
AL	11	1st	29.33	0	0	0	69.99	93.51	0.75	13.67	1.59	23.31	0.42	30.23
AL	11	2nd	20.59	0	8.92	25.46	31.83	223.6	0.3	15.07	1.98	14.65	0.77	67.57
AL	11	3rd	16.25	0	4.86	35.41	43.48	282.92	0.3	10.3	1.65	22.27	0.66	73.43
AL	11	4th	52.07	0	0	0	47.93	80.85	0.59	12.87	1.43	11.43	0.5	———
AL	11	5th	16.34	0	3.36	18.56	61.74	564.49	0.15	4.48	2	31.68	0.56	57.51
AL	12	1st	29.12	0	0	0	54.69	111.58	0.49	21.04	2.43	7.17	0.6	51.26
AL	12	2nd	0	0	0	0	99.93	614.25	0.16	0.29	1.86	36.67	0	———
AL	12	3rd	0	0	22.93	0	77.07	606.17	0.16	0	1.83	37.6	0.35	———
AL	12	4th	0	0	46.37	2.58	51.05	512.43	0.2	0	1.48	46.09	0.52	82.19
AL	12	5th	0	0	4.49	40.31	55.21	618.97	0.16	0	1.88	36.2	0.53	40.64
AL	13	1st	7.89	0	0	50.13	32.87	273.19	0.3	10.12	1.82	24.34	0.63	72.36
AL	13	2nd	31.07	0	0	47	0	61.01	0.77	20.62	1.75	3.22	0.66	60.1
AL	13	3rd	46.46	0	0	12.47	40.83	116.99	0.46	21.88	2.24	4.43	0.6	33.49
AL	13	4th	7.69	0	0	0	82.96	90.4	0.92	15.59	1.78	23.35	0.3	59.79
AL	13	5th	40.8	0	0	0	53.68	42.95	1.25	18.29	1.32	11.48	0.54	47.1
AL	15	1st	9.64	0	0	0	79.13	266.73	0.3	14.81	2.34	20.67	0.36	53.78
AL	15	2nd	38.92	0	0	0	55.58	94.3	0.59	23.11	1.95	4.32	0.54	39.34
AL	15	3rd	43.15	0	0	0	52.77	71.99	0.73	14.76	1.47	14.91	0.53	38.17
AL	15	4th	30.51	0	0	7.38	59.18	149.62	0.44	12.24	1.63	19.41	0.55	45.64
AL	15	5th	26.65	0	0	16.05	57.3	99.14	0.74	13.73	1.6	18.14	0.57	60.99
AL	16	1st	22.63	0	0	0	77.37	139.56	0.55	13.01	1.39	21.94	0.35	———
AL	16	2nd	48.48	0	0	0	51.52	74.1	0.7	16.13	1.55	9.74	0.5	———
AL	16	3rd	53.64	0	0	0	44.1	45.2	0.98	13.58	1.56	15.22	0.52	36.86
AL	16	4th	30.06	0	0	4.79	65.15	83.81	0.83	16.19	1.54	16.93	0.48	42.41
AL	16	5th	43.55	0	0	7.72	24.06	18.95	1.68	19.71	1.31	0.32	0.71	64.96
AL	17	1st	7.95	0	0	0	76.77	258.87	0.3	14.04	2.37	17.13	0.38	74.44
AL	17	2nd	3.83	0	0	0	84.78	283.63	0.3	9.97	1.89	25.15	0.27	60.77
AL	17	3rd	0	0	0	0	97.15	329.64	0.29	4.17	1.52	32.4	0.06	54.75
AL	17	4th	18.44	0	0	0	69.27	116.38	0.6	14.4	1.67	19.02	0.48	69.55
AL	17	5th	11.28	0	0	0	86.55	579.08	0.15	10.38	2.64	21.41	0.24	35.95
AL	1	1st	53.21	0	0	0	39.84	38.69	1.03	17.62	1.47	6	0.56	59.37
AL	1	2nd	36.64	0	9.82	0	25.79	47.63	0.75	18.39	1.47	1.3	0.72	66.23
AL	1	3rd	83.13	0	0	0	12.02	9.16	1.31	10.51	1.34	0	0.29	77.42
AL	1	4th	54.5	0	0.98	0	41.51	58.01	0.73	15.38	1.66	6.08	0.53	40.14
AL	1	5th	42.21	0	1.3	0	42.93	151.79	0.29	12.14	1.92	15.64	0.63	64.79
AL	22	1st	92.98	0	0	0	4.81	11.07	0.43	4.08	1.37	0	0.13	58.42
AL	22	2nd	61.64	0	4.5	0	32.23	31.29	1.17	13.57	1.48	15.01	0.51	63.43

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt #	Partial Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	22	3rd	76.78	0	0	0	15.25	25.94	0.59	8.04	1.53	5.22	0.38	54.6
AL	22	4th	63.92	0	0	0	33.18	45.28	0.73	13.18	1.68	8.87	0.48	34.03
AL	22	5th	46.33	0	12.36	0	41.31	60.78	0.88	22.99	1.61	4.88	0.6	55.4
AL	23	1st	22.1	0	0	0	77.9	256.81	0.3	7.67	1.8	25.62	0.34	-------
AL	23	2nd	6.5	0	0	0	93.5	206.07	0.45	3.66	1.63	35.8	0.12	-------
AL	23	3rd	19.14	0	0	0	79.38	263.36	0.3	11.41	2.05	22.35	0.33	29.88
AL	23	4th	32.37	0	0	0	63.64	105.59	0.6	13.19	1.7	19.6	0.49	38.84
AL	23	5th	26.02	0	0	0	68.55	151.48	0.45	16.74	1.72	13.53	0.46	54.63
AL	24	1st	65.87	0	0	2.21	31.92	34.15	1	11.03	1.61	14.26	0.46	45.1
AL	24	2nd	18.18	0	0	0	81.82	140.24	0.58	8.22	1.68	25.47	0.3	-------
AL	24	3rd	10.62	0	0	51.33	37.99	621	0.14	7.1	2.48	29.78	0.58	58.45
AL	24	4th	59.1	0	0	7.18	29.36	42.35	0.86	18.2	1.56	2.23	0.56	56.23
AL	24	5th	24.43	0	0	0	73.8	513.46	0.14	14.33	3.15	17.24	0.4	39.54
AL	25	1st	59.01	0	0	7.71	31.36	32.92	1.19	19.18	1.71	5.87	0.55	49.67
AL	25	2nd	60.06	0	0	0	39.94	34.03	1.17	18.62	1.69	8.26	0.48	-------
AL	25	3rd	66.93	0	0	0	32.44	24.64	1.32	19.91	1.53	0.45	0.45	23.21
AL	25	4th	49.69	0	0	0	45.82	62.3	0.74	17.83	1.73	5.31	0.54	41.61
AL	25	5th	3.09	0	0	5.21	86.24	312.55	0.29	6.33	1.93	30.37	0.25	70.27
AL	26	1st	20.07	0	0	4.94	65.44	233.97	0.3	17.81	2.37	9.03	0.53	52.89
AL	26	2nd	27.6	0	0	15.9	56.5	123.72	0.59	14.16	1.62	18.99	0.58	58.91
AL	26	3rd	41.32	2.12	0	0	53.55	94.16	0.59	16.25	1.74	14.46	0.54	48.01
AL	26	4th	55.35	1.59	0	0	39.15	46.47	0.88	18.34	1.68	3.89	0.54	43.97
AL	26	5th	42.88	0	0	0	57.12	130.24	0.44	18.86	2.17	4.05	0.49	-------
AL	28	1st	13.78	0	4.81	30.52	41.64	174.85	0.44	16.66	1.94	15.93	0.7	82.25
AL	28	2nd	35.85	0	0	26.01	35.31	208.46	0.29	13.12	2.06	19.72	0.68	52.81
AL	28	3rd	19.24	0	9.05	10.71	59.89	268.95	0.3	4.34	1.75	33.78	0.58	69.89
AL	28	4th	21.18	0	2.67	25.2	50.95	267.88	0.29	10.65	1.92	20.47	0.63	66.66
AL	28	5th	36.15	0	0	1.14	44.65	62.25	0.74	12.69	2.41	9.11	0.65	56.61
AL	29	1st	20.25	0	0	0	78.81	260.23	0.3	8.16	1.79	24.32	0.34	42.31
AL	29	2nd	47.83	0	0	0	43.79	72.51	0.6	15.57	1.62	8.69	0.58	50.18
AL	29	3rd	13.16	0	0	0	86.84	577.4	0.15	4.6	2.06	30.32	0.23	-------
AL	29	4th	55.22	0	0	0	44.78	98.96	0.45	12.33	1.72	10.31	0.49	-------
AL	29	5th	61.66	0	0	0	28.86	38.5	0.75	9.35	1.44	13.29	0.53	42.97
AL	2	1st	64.16	0	4.19	0	28.16	44.08	0.73	6.08	1.37	22.05	0.51	62.83
AL	2	2nd	0	0	0	0	99.42	641.13	0.16	1.13	1.93	33.32	0.01	-------
AL	2	3rd	19.07	0	0	3.71	77.23	271.94	0.3	9.01	1.76	25.12	0.37	58.63
AL	2	4th	85.89	0	0	2.77	10.82	13.01	1.04	8.63	1.99	0	0.25	44.98
AL	2	5th	83.87	0	0	0	15.55	10.41	1.49	13.47	1.48	0	0.27	25.28
AL	30	1st	63.82	0	0	0	35.76	19.1	1.87	22.53	1.64	0.01	0.46	15.6
AL	30	2nd	70.39	0	0	0	29.61	14.66	2.02	20.75	1.37	2.84	0.42	-------
AL	30	3rd	78.81	0	0	0	21.19	14.74	1.44	13.22	1.57	3.99	0.33	-------
AL	30	4th	86.23	0	0	0	7.04	5.36	1.31	7.9	1.49	0	0.25	60.29

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt	Partial	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#	Rt						(ha)	(no/	(m/ha)		(%)		(%)
									100 ha)					
AL	30	5th	90.03	0	0	0	6.33	6.3	1	7.67	1.41	0	0.18	71.83
AL	31	1st	72.08	0	0	2.1	22.69	20.75	1.19	15.68	1.44	4.56	0.43	51.66
AL	31	2nd	78.59	0	0	9.84	11.56	16.19	1.32	14.26	1.45	0	0.36	72.43
AL	31	3rd	81.45	0	0	6.81	9.98	28.11	0.6	11.55	1.37	0	0.32	52.51
AL	31	4th	80.24	0	0	0	19.76	13.46	1.47	14	1.35	0	0.32	———
AL	31	5th	59.45	0	0	0	34.25	23.22	1.48	22.29	1.36	0.69	0.53	48.7
AL	32	1st	60.74	0	0	0	22.36	13.47	1.66	16.6	1.57	0	0.57	47.8
AL	32	2nd	72.71	0	0	0	26.4	14.63	1.8	19.42	1.5	0	0.4	33.51
AL	32	3rd	54.13	0	0	3.88	40.75	36.49	1.22	17.2	1.56	9.43	0.54	41.35
AL	32	4th	72.52	0	0	0.6	23.21	12.2	1.95	19.15	1.37	0	0.42	43.59
AL	32	5th	79.34	0	0	0	19.09	13.88	1.38	14.59	1.57	0	0.33	33.68
AL	34	1st	47.73	0	0	0	51.21	59	0.87	19.46	1.66	7.86	0.51	19.09
AL	34	2nd	38.76	0	0	16.62	44.61	70.47	0.87	8.14	1.51	26.11	0.62	91.73
AL	34	3rd	18.79	0	0	26.07	55.13	563.01	0.14	9.13	2.61	22.36	0.59	75.16
AL	34	4th	24.44	0	0	0.43	75.13	174.64	0.43	5.74	1.72	27.84	0.38	32.35
AL	34	5th	13.78	0	0	6.21	80.01	298.8	0.29	5.71	1.77	32.98	0.34	63.07
AL	35	1st	22.87	0	0	77.13	0	265.66	0.29	11.07	2.58	24.18	0.35	———
AL	35	2nd	25.49	0	0	70.66	0	161.74	0.44	10.46	2.17	22.75	0.43	41.15
AL	35	3rd	4.32	0	0	95.3	0	657.53	0.14	3.69	2.28	31.99	0.09	39.69
AL	35	4th	11.46	0	0	16.02	66.68	285.27	0.29	13.09	2.93	20.42	0.51	60.1
AL	35	5th	18.44	0	1.09	13.86	61.33	263.47	0.29	15.53	2.15	14.84	0.57	59.15
AL	36	1st	15.45	0	0	0	77.89	529.68	0.15	13.89	2.93	15.27	0.37	45.38
AL	36	2nd	2.74	0	0	0	95.15	651.63	0.15	4.05	2.25	29.3	0.09	69.2
AL	36	3rd	0	0	0	0	100	684.62	0.15	0	1.97	36.23	0	———
AL	36	4th	14.63	0	0	0	85.08	581.62	0.15	2.31	1.96	34.41	0.25	43.37
AL	36	5th	69.38	0	0	1.15	7.22	9.48	0.88	6.96	1.58	0	0.48	62.89
AL	37	1st	14.96	0	0	3.01	82.04	290.63	0.29	7.63	1.89	27.46	0.3	44.13
AL	37	2nd	5.84	0	0	0	94.16	641.96	0.15	4.23	2.27	31.4	0.11	———
AL	37	3rd	23.73	0	0	0	76.27	173.8	0.44	12.97	1.76	19.97	0.36	———
AL	37	4th	44.14	0	0	1.08	53.79	93.33	0.59	17.3	2.1	13.05	0.52	33.45
AL	37	5th	40.62	0	0	6.69	52.69	101.38	0.59	12.8	1.57	14.2	0.55	56.49
AL	38	1st	20.15	0	0	0	79	178.98	0.44	12.39	1.82	24.77	0.34	44.41
AL	38	2nd	47.09	0	0	0	50.68	85.94	0.59	17.18	1.79	11.74	0.52	36.28
AL	38	3rd	1.73	0	0	4.93	90.82	650.37	0.15	4.08	2.16	32.57	0.17	53.04
AL	38	4th	6.75	0	0	0.72	92.52	630.88	0.15	4.03	2.09	32.39	0.14	57.91
AL	38	5th	83.7	0	0	0.42	14.83	20.21	0.75	8.38	1.38	0	0.28	38.19
AL	41	1st	0	14.32	0	0.26	0	43.4	0.34	6.01	4.34	0	0.82	74.21
AL	41	2nd	0	18.51	0	8.55	0	83.1	0.33	9.33	1.57	0.11	0.84	79.06
AL	41	3rd	0	0	0	0	48.24	66.21	0.73	14.09	1.47	19.44	0.69	70.04
AL	41	4th	0	18.34	0	0	55.01	507.97	0.14	10.9	2.43	22.04	0.63	71.41
AL	41	5th	0	0	0	5.24	23.82	100.34	0.29	9.53	1.64	13.92	0.69	67.2
AL	43	1st	8.37	0	0	0	73.92	251.92	0.29	12.97	2.15	21.94	0.43	58.41

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt #	Partial Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	43	2nd	39.62	0	0	0	60.38	82.67	0.73	15.71	1.85	14.26	0.48	—
AL	43	3rd	22.38	0	0	0	76.86	103.96	0.74	12.32	1.53	26.05	0.36	41.12
AL	43	4th	0	0	0	0	98.88	332.66	0.3	3.26	1.53	34.34	0.02	26.41
AL	43	5th	0	0	0	0	97.01	657.67	0.15	2.82	2.17	32.45	0.06	40.02
AL	44	1st	0	0	0	0	8.03	27.13	0.3	6.55	1.48	0	0.57	68.62
AL	44	2nd	0	0	0	0	3.01	20.12	0.15	2.86	1.33	0	0.57	71.54
AL	44	3rd	0	0	0	0	0	—	—	—	—	—	0.43	68.98
AL	44	4th	0	0	0	0	2.28	15.34	0.15	1.82	1.13	0	0.34	55.66
AL	44	5th	4.45	0	0	0	0.95	2.16	0.44	1.22	1.62	0	0.61	63.89
AL	4	1st	30.86	0	0	0	48.63	65.96	0.74	14.05	1.6	17.53	0.65	74.78
AL	4	2nd	31.72	0	0	1.82	63.18	88.28	0.74	17.35	1.57	13.37	0.5	51.36
AL	4	3rd	65.88	0	0	0.49	30.1	34.92	0.88	18.01	1.89	0.02	0.47	31.42
AL	4	4th	65.01	0	0.87	0	28.21	22.15	1.31	16.06	1.6	0.66	0.5	49.11
AL	4	5th	36.07	0	0	2.57	60.08	106.87	0.59	15.46	1.6	10.72	0.51	39.18
AL	5	1st	37.09	0	0	0	62.07	70.88	0.88	12.23	1.76	20.6	0.48	31.88
AL	5	2nd	69.44	0	0	0	27.77	47.57	0.58	13.93	2.12	3.37	0.44	37.68
AL	5	3rd	69.96	0	0	0	20.59	12.77	1.61	14.1	1.37	0	0.46	63.26
AL	5	4th	70.72	0	0	0	29.28	20.08	1.46	16.92	1.62	4.5	0.41	—
AL	5	5th	64.95	0	0	1.53	23.39	18.97	1.31	15.29	1.35	0.47	0.52	43.82
AL	6	1st	49.28	0	0	0	50.04	56.98	0.88	20.26	1.67	6.07	0.51	22.75
AL	6	2nd	52.24	0	0	2.66	39.6	42.15	1	17.39	1.47	7.33	0.57	43.84
AL	6	3rd	68.99	0	0	0	9.07	18.13	0.5	4.96	1.32	2.45	0.49	63.4
AL	6	4th	6.04	0	0	0	0	—	—	—	—	—	0.78	70.95
AL	6	5th	9.56	11.17	19.5	0	0	48.28	0.64	13.18	1.49	0.09	0.69	76.82
AL	7	1st	59.41	0	0	0	37.73	127.16	0.3	11.38	1.8	0.54	0.5	53.75
AL	7	2nd	63.6	0	0.32	0	36.08	124.2	0.29	11.08	1.85	0.09	0.47	19.86
AL	7	3rd	73.75	0	0	0	22.75	22.17	1.03	12.19	1.38	0	0.4	71.15
AL	7	4th	74.79	0	0	0	24.76	27.9	0.89	12.47	1.68	0	0.38	22.29
AL	7	5th	47.02	0	0	0	37.99	128.95	0.29	10.16	1.72	7.1	0.63	65.82
AL	8	1st	65.58	0	0	6.59	25.32	27.29	1.17	18.68	1.52	0.1	0.5	41.37
AL	8	2nd	52.37	0	12.58	4.67	30.38	81.27	0.59	11.16	1.33	14.04	0.62	74.61
AL	8	3rd	42.38	0	0.06	6.32	21.85	31.97	0.88	10.07	1.48	8.43	0.74	63.81
AL	8	4th	20.13	0	15.71	0	9.08	56.13	0.44	7.89	1.45	5.02	0.71	82.76
AL	8	5th	21.19	0	24.13	8.3	46.37	267.06	0.3	6.13	1.58	27.45	0.67	80.04
AL	9	1st	73.28	0	0.83	0	24.25	34.21	0.73	11.44	1.65	5.48	0.4	42.98
AL	9	2nd	79.34	0	2.79	0	16.74	44.64	0.44	7.64	1.22	7.37	0.34	52.9
AL	9	3rd	91.28	0	7.25	1.47	0	19.93	0.44	5.51	1.33	0	0.16	51.08
AL	9	4th	95.72	0	0	0.03	4.25	14.61	0.29	2.47	1.21	0	0.08	24.88
AL	9	5th	61.95	0	32.28	0	0	220.67	0.15	5.37	1.81	11.37	0.51	82.72
FL	1	1st	27.59	0	0	65.38	3.88	118.71	0.58	16.2	1.59	11.66	0.49	56.27
FL	1	2nd	37.58	0	0	59.45	2.95	85.73	0.73	16.58	1.68	14.37	0.5	32.66
FL	1	3rd	2.27	13.82	0	76.79	4.41	647.26	0.15	4.21	2.21	30.91	0.39	50.63

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt #	Partial Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
FL	1	4th	3.38	9.23	0	55.76	12.16	128.96	0.6	16.79	1.88	17.54	0.65	72.57
FL	1	5th	26.85	0	0	37.01	6.74	33.23	1.32	23.7	2.1	1.56	0.73	60.75
FL	2	1st	0	8.13	0	61.97	0	67.24	1.04	10.78	1.7	24.23	0.58	63.42
FL	2	2nd	0	0	0	32.56	0	22.91	1.42	24.59	1.61	0	0.76	74.35
FL	2	3rd	0	0	0	19.06	0	27.91	0.68	14.76	2.12	0	0.82	85.61
FL	2	4th	0	0	0	17.41	0	110.39	0.16	7.82	1.77	1.55	0.71	72.73
FL	2	5th	0	10.48	0	0.22	0	12.41	0.86	9.92	1.47	0	0.75	63.57
FL	3	1st	0	0	0	66.96	12.95	279.14	0.29	8.54	1.74	27.67	0.52	65.91
FL	3	2nd	0	0	0	88.72	4.76	653.79	0.14	4.23	2.22	29.32	0.21	66.45
FL	3	3rd	0	6.38	0	83.99	0	632.88	0.14	5.67	2.32	26.37	0.28	55.51
FL	3	4th	0	0	0	74.2	0.02	129.68	0.57	9.5	1.69	26.89	0.43	65.21
FL	3	5th	21.21	2.67	0	52.08	4.82	83.37	0.71	15.99	1.72	18.03	0.67	69.79
FL	4	1st	40.92	6.25	0	42.47	8.65	65.65	0.87	19.64	1.5	9.39	0.64	63.93
FL	4	2nd	44.42	4.2	0	42.85	7.92	62.2	0.88	25.36	2.13	4.7	0.61	50.89
FL	4	3rd	42.46	2.63	0	53.1	0	126.97	0.44	14.64	1.7	8.45	0.54	46.02
FL	4	4th	9.26	10.11	0	75.35	0	292.21	0.29	11.58	2.02	17.07	0.41	64.18
FL	4	5th	8.12	4.81	0	87.07	0	314.49	0.29	4.01	1.94	32.37	0.23	62.89
FL	5	1st	2.13	10.36	0	87.51	0	663.54	0.15	1.61	2.03	34.04	0.22	33.96
FL	5	2nd	4.7	14.54	0	80.76	0	648.61	0.15	2.19	2.09	33.59	0.32	35.47
FL	5	3rd	24.55	2.23	0	67.97	4.21	101.52	0.73	12.78	2.05	26.16	0.48	56.25
FL	5	4th	18.16	3.2	0	71.06	2.25	522.44	0.15	16.82	3.18	9.79	0.46	53.56
FL	5	5th	2.52	9.75	0	52.36	9.69	245.09	0.29	10.82	1.91	18.22	0.68	80.71
FL	6	1st	36.79	2.05	0	51.66	1.57	63.2	0.87	27.53	1.87	2.28	0.59	45.31
FL	6	2nd	29.01	0	0	66.47	3.45	95.54	0.73	19.96	1.93	17.02	0.47	39.58
FL	6	3rd	41.76	0	0	50.48	0.65	67.45	0.76	24.55	1.83	0.21	0.57	36.86
FL	6	4th	12.06	0	0	50.88	0	86.9	0.59	18.9	1.98	1.59	0.65	73.52
FL	6	5th	7.87	0.67	0	89.97	0.19	308.49	0.29	8.51	1.79	25.52	0.18	47.65
FL	7	1st	0.05	17.25	0	74.96	5.81	676.07	0.14	2.47	2.11	33.17	0.4	34.93
FL	7	2nd	2.37	0	0	57.43	26.98	292.34	0.29	12.86	2.46	21.52	0.59	62.57
FL	7	3rd	0	0.01	3.19	46.26	46.19	329.12	0.29	5.22	1.91	30.98	0.57	40.04
FL	7	4th	22.27	12.65	0	1.84	59.84	100.29	0.74	16.07	1.57	20.78	0.58	54.26
FL	7	5th	29.41	8.87	0	11.48	47.66	76.51	0.89	24.41	1.76	8.74	0.66	55.34
FL	8	1st	56.93	2.94	0	15.97	22.89	40.19	1.04	28.48	1.87	0.11	0.6	51.71
FL	8	2nd	32.59	7.12	0	25.89	25.61	65.86	0.89	27.47	1.74	3.15	0.75	57.22
FL	8	3rd	0	0.41	0	80.93	14.18	650.07	0.15	2.44	2.06	33.68	0.32	37.99
FL	8	4th	0	15.24	0	77.86	6.9	684.49	0.15	0	1.97	36.14	0.37	86.99
FL	8	5th	0.08	0	0	96.18	3.75	684.44	0.15	0.33	1.97	36.12	0.07	23.3
FL	9	1st	0	0	0	77.15	0	528.33	0.15	18.56	2.77	14.65	0.38	61.25
FL	9	2nd	0	0	0	61.54	0	132.81	0.46	19.44	1.69	12.15	0.58	71.18
FL	9	3rd	0	0	0	82.9	0	567.91	0.15	13.31	2.24	22.63	0.29	29.63
FL	9	4th	0	0	0	75.59	8.2	551.32	0.15	13.91	2.24	22.71	0.41	65.33
FL	9	5th	0	1.86	0	84.38	10.26	661.15	0.15	5.84	2.41	25.78	0.28	53.72

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt #	Partial Rt	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
GA	10	1st	80.14	0	11.79	5.7	2.37	22.55	0.88	12.55	1.41	2.03	0.34	60.91
GA	10	2nd	75.96	7.89	3.29	11.22	1.64	82.03	0.29	7.2	1.63	19.2	0.4	73.03
GA	10	3rd	68.84	14.46	3.93	1.98	0	34.43	0.59	12.58	1.79	1.58	0.5	53.77
GA	10	4th	59.78	12.02	2.64	8	17.31	54.58	0.73	13.73	1.37	6.42	0.59	51.4
GA	10	5th	53.39	0	8.08	19.99	0	46.63	0.6	10.01	1.41	14.4	0.64	54.66
GA	16	1st	25.68	0	0	6.42	64.75	118.36	0.6	8	1.7	27.25	0.51	58.83
GA	16	2nd	36.02	0	8.75	0	48.95	97.45	0.59	14.18	1.63	15.92	0.62	57.9
GA	16	3rd	24.67	0	8.21	13.37	50.59	163.59	0.44	11.01	1.74	22.12	0.66	69.76
GA	16	4th	20.12	2.57	0	3.27	70.09	255.93	0.3	12.72	2.02	20.4	0.47	50.61
GA	16	5th	56.81	0	4.09	9.18	29.92	36.17	1.19	18.07	1.75	8.43	0.58	56.07
GA	22	1st	67.31	4.36	10.51	0	17.82	37.85	0.86	10.76	1.47	13.14	0.5	85.26
GA	22	2nd	70.77	0	0	0	22.07	25.56	0.86	12.57	1.42	1.01	0.45	42.77
GA	22	3rd	62.77	0	0	0.87	36.36	32.31	1.15	20.05	1.68	0	0.47	13.57
GA	22	4th	41.18	0	0.45	3.8	50.53	54.06	1.01	17.85	1.62	14.63	0.57	55.92
GA	22	5th	35.23	11.87	8.03	0	26.99	32.47	1.44	25.33	1.6	5.42	0.77	70.6
GA	25	1st	61.59	4.83	17.63	0.21	0.27	39.19	0.59	15.52	1.74	0	0.57	45.87
GA	25	2nd	50	0	14.42	13.95	1.81	41.09	0.73	14.35	1.69	4.32	0.69	59.54
GA	25	3rd	85.99	0	10.85	0.01	2.45	13.02	1.02	10.48	1.4	0	0.25	39.73
GA	25	4th	65.25	0	0	23.19	8.01	42.8	0.73	9.9	1.24	10.8	0.51	68.01
GA	25	5th	74.27	0	0	20.25	2.34	25.48	0.89	10.52	1.55	6.34	0.41	58
GA	26	1st	10.92	0	38.31	18.87	31.9	301.43	0.3	4.27	2.31	30.94	0.7	76.98
GA	26	2nd	55.3	0	13.24	5.86	23.09	95.44	0.44	9.33	1.5	13.37	0.62	68.83
GA	26	3rd	50.95	0	0.98	8.01	29.01	32.38	1.17	14.91	1.56	10.39	0.64	61.8
GA	26	4th	23.1	0	0	0.72	40.87	56.32	0.74	13.73	1.39	13.97	0.71	65.49
GA	26	5th	25.79	0	0	23.94	50.2	504.39	0.15	10.95	2.49	18.68	0.62	59.57
GA	28	1st	53.9	0	0	27.94	13.28	78.24	0.53	8.86	1.42	14.02	0.61	64.24
GA	28	2nd	85.79	0	0	14.21	0	21.59	0.66	8.61	1.41	0	0.24	-------
GA	28	3rd	81.9	0	0	18.1	0	27.36	0.66	11.95	1.48	0.37	0.3	-------
GA	28	4th	70.69	0	0	0	29.31	55.51	0.53	13.05	1.71	0.55	0.41	-------
GA	28	5th	62.36	0	0	13.62	24.02	56.26	0.67	10.97	1.39	17.28	0.53	54.49
GA	33	1st	72.83	0	0.84	4.2	18.89	32.13	0.75	10.66	1.39	0.95	0.43	57.08
GA	33	2nd	76.89	0	4.32	13.52	0	40.55	0.44	8.65	1.65	0	0.39	61.6
GA	33	3rd	17.98	0	0	0	14.47	32.87	0.44	5.82	1.34	2.41	0.69	58.12
GA	33	4th	45.17	8.57	8.26	13.34	24.66	93.11	0.59	14.01	1.41	16.69	0.7	67.29
GA	33	5th	54.54	0	18.82	12.98	13.67	38.05	1.19	13.63	1.51	17.24	0.63	86.68
GA	36	1st	44.54	0	2.92	14.12	23.03	34.12	1.17	15.3	1.48	12.68	0.71	70.5
GA	36	2nd	47.93	0	15.89	0	36.17	43.8	1.19	25.45	1.42	2.79	0.61	59.98
GA	36	3rd	34.08	0	28.49	0	36.05	87.46	0.74	20.79	1.83	9.3	0.67	68.57
GA	36	4th	18.36	0	16.89	0	57.4	167.91	0.44	15.48	1.85	18.54	0.6	65.83
GA	36	5th	13.23	0	2.75	24.92	38.35	106.43	0.62	17.09	1.57	13.56	0.74	64.75
GA	37	1st	36.38	0	0	6.81	56.81	145.13	0.44	13.81	2.2	11.96	0.54	47.79
GA	37	2nd	19.15	0	18.55	6.13	56.16	273.51	0.3	10.21	2.29	23.2	0.61	69.87

Table C3. (cont'd) Value of each of the 12 metrics for each study site for Extent 3.

State	Rt	Partial	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#	Rt						(ha)	(no/	(m/ha)		(%)		(%)
									100 ha)					
GA	37	3rd	47.75	0	23.32	0	28.93	116.32	0.45	13.21	1.87	8.91	0.63	62.85
GA	37	4th	16.4	0	0	47.45	30.27	132.57	0.59	12.03	1.93	18.48	0.65	77.48
GA	37	5th	21.33	0	9.54	23	46.13	537.93	0.15	9.81	2.43	18.29	0.68	80.23
GA	38	1st	30.67	1.14	1.53	0	49.69	59.14	0.89	17.31	1.41	8.72	0.65	54.97
GA	38	2nd	26.45	2.29	1.46	8.63	57.43	119.45	0.58	11.86	1.57	23.13	0.59	62.77
GA	38	3rd	40.11	5.15	0.17	2.36	49.98	98.25	0.59	11.77	1.68	20.13	0.59	52.35
GA	38	4th	21.54	2.51	0	43.76	32.18	267.54	0.29	11.73	1.9	19.48	0.66	65.16
GA	38	5th	8.55	4.91	0	73.38	13.16	626.38	0.15	4.56	2.27	28.81	0.43	74.75
GA	6	1st	71.83	0	0	20.29	6.2	20.09	1.32	15.76	1.45	0	0.44	40.62
GA	6	2nd	60.29	0	0	22.28	17.43	67.62	0.59	12.56	1.65	11.51	0.56	97.19
GA	6	3rd	82.98	0	0	11.99	4.07	12.21	1.32	12.1	1.28	0.09	0.3	51.3
GA	6	4th	36.1	0	15.89	2.75	44.49	107.19	0.59	14.9	1.59	17.61	0.65	54.45
GA	6	5th	58.2	0	22.38	7.23	4.91	47.21	0.73	11.45	1.44	9.58	0.6	62.59

Table C4. Value of each of the 12 metrics for each study site for Extent 4.

State	Rt	Partial	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#	PART						(ha)	(no/	(m/ha)		(%)		(%)
									100 ha)					
AL	10	1st	16.44	0	29.45	9.07	43.28	7562.24	0.01	7.01	2.18	74.86	0.69	41.41
AL	10	2nd	16.26	0	26.39	14.06	41.58	7227.61	0.01	6.93	2.17	75.23	0.71	42.02
AL	10	3rd	11.68	0	29.04	13.53	43	6613.04	0.01	6.27	1.94	78.34	0.7	49.15
AL	10	4th	11.2	0	26.33	12.31	47.43	9735.39	0.01	6.13	2.12	78.24	0.68	55.71
AL	10	5th	10.92	0	23.82	14.18	47.68	7876.72	0.01	6	2.06	79.23	0.68	47.47
AL	11	1st	17.98	0	4.61	3.63	57.4	1197.67	0.05	8.57	1.7	68.67	0.62	58.74
AL	11	2nd	17.72	0	6.83	4.41	62.51	1559.04	0.05	8.38	1.65	71.88	0.57	52.26
AL	11	3rd	18.75	0	7.97	5.6	61.03	1738.79	0.04	7.87	1.65	72.86	0.58	47.51
AL	11	4th	19.41	0	7.56	8.32	60.77	5912.96	0.01	8.1	2.29	71.62	0.58	43.52
AL	11	5th	25.16	0	5.86	8.33	57.76	1769.34	0.04	8.43	1.65	69.75	0.59	40.65
AL	12	1st	17.75	0	6.19	5.35	54.33	1515.91	0.04	6.91	1.82	73.66	0.66	58.23
AL	12	2nd	16.77	0	12.45	9.35	57.45	1830.56	0.04	6.71	1.69	77.62	0.62	52.57
AL	12	3rd	10.04	0	18.74	13.91	56.06	5514.91	0.02	4.37	2.11	84.72	0.62	48.87
AL	12	4th	6.38	0	22.22	16.73	54.38	6097.61	0.02	2.91	1.94	88.73	0.62	49.69
AL	12	5th	5.11	0	23.88	14.51	56.03	21179.61	0	2.89	1.81	88.92	0.61	53.63
AL	13	1st	14.13	0	0.45	19.62	57.53	3952.78	0.02	9.02	2.32	68.58	0.61	49.23
AL	13	2nd	13.1	0	1.28	23.56	57.07	6129.16	0.01	8.27	2.69	72.53	0.6	54.22
AL	13	3rd	12.32	0	1.38	15.81	64.05	4698.65	0.02	8.69	2.48	71.85	0.55	54.23
AL	13	4th	15	0	1.66	8.77	65.07	2284.73	0.03	9.65	2.05	67.32	0.54	53.69
AL	13	5th	17.13	0	0.41	4.37	63.99	2362.34	0.03	10.95	2.44	58.77	0.55	48.65
AL	15	1st	13.21	0	0	0.67	76.99	3529.15	0.02	11.46	2.2	61.61	0.39	37.31
AL	15	2nd	19.78	0	0	0.76	72.63	2967.68	0.02	12.77	2.25	55.1	0.43	31.94
AL	15	3rd	22.23	0	0	1.31	69.74	2322.85	0.03	13.6	2.17	51.66	0.46	33.37
AL	15	4th	24.93	0	0	0.75	67.77	3056.45	0.02	14.84	2.62	46.69	0.48	31.3
AL	15	5th	23.88	0	0	0.85	71.22	2557.93	0.03	13.54	2.43	52.78	0.44	25.19
AL	16	1st	16.46	0	0	1.53	80.64	19314.54	0	7.6	3.69	71.66	0.32	17.26
AL	16	2nd	19	0	0	0.7	80	12456.12	0.01	8.27	2.95	69.54	0.32	9.37
AL	16	3rd	23.11	0	0	2.16	73.47	3539.3	0.02	10.21	2.09	63.42	0.41	19.85
AL	16	4th	25.58	0	0	3.94	69.01	4127.97	0.02	11.92	2.3	57.06	0.46	23
AL	16	5th	20.76	0	0	4.02	72.97	5758.3	0.01	11.44	2.78	59.99	0.42	25.82
AL	17	1st	3.09	0	0	2.08	76.18	5127.43	0.02	8.37	2.1	70.51	0.41	55.57
AL	17	2nd	2.46	0	0	1.63	85.48	19268.48	0	7.53	4.08	74.01	0.27	57.28
AL	17	3rd	2.06	0	0	2.72	83.75	13101.18	0.01	8.4	2.99	71.55	0.29	54.65
AL	17	4th	2.6	0	0	3.26	82.07	9782.71	0.01	9.41	3.32	67.6	0.32	54.57
AL	17	5th	4.6	0	0	2.53	81.62	7611.94	0.01	10.22	2.72	66.12	0.33	49.83
AL	1	1st	38.7	0.48	16.39	0.42	24.23	287.34	0.14	14.54	1.67	29.81	0.75	48.54

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt #	Partial PART	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	29	1st	17.76	0	2.47	4.77	72.1	5204.91	0.02	6.71	2.14	75.05	0.45	41.39
AL	29	2nd	16.43	0	0.43	5.38	76.32	4642.44	0.02	6.51	1.69	76.83	0.39	31.97
AL	29	3rd	20.12	0	0	2.07	77.48	7389.5	0.01	6.81	2.01	74.37	0.36	20.35
AL	29	4th	28.02	0	0.08	1.24	69.64	2168.79	0.03	8.31	1.69	67.4	0.44	21.87
AL	29	5th	32.2	0	0.08	1.36	65	2362.5	0.03	9.44	1.76	61.3	0.47	23.15
AL	2	1st	58.66	0.14	2.51	0.41	32.26	201.66	0.18	10.4	1.41	39.21	0.55	28.92
AL	2	2nd	59.43	0.14	1.87	0.34	36.16	214	0.18	10.69	1.39	42.03	0.52	25.12
AL	2	3rd	59.56	0	1.84	0.52	35.86	272.93	0.14	10.26	1.46	43.78	0.52	24.88
AL	2	4th	59.6	0.14	1.51	0.75	35.03	301.3	0.12	9.44	1.56	45.93	0.52	27.77
AL	2	5th	61.7	0	2.4	0.26	33.69	323	0.11	9.59	1.5	42.83	0.51	25.28
AL	30	1st	42.4	0.01	0.17	0.19	53.49	677.13	0.08	16.16	1.94	35.43	0.53	20.48
AL	30	2nd	52.91	0.18	0.25	1.95	41.15	358.87	0.12	16.15	1.78	26.51	0.55	23.42
AL	30	3rd	54.66	0.98	0.17	1.87	39.55	445.52	0.1	15.86	1.87	25.71	0.54	19.77
AL	30	4th	56.17	1.21	0.06	2.47	38.82	457.19	0.09	16.69	1.94	22.12	0.53	17.92
AL	30	5th	58.3	0.63	0.1	0.89	39.03	532.91	0.08	16.21	2.17	21.89	0.51	14.43
AL	31	1st	56.2	7.12	0	7.32	27.83	209.12	0.2	17.05	1.62	25	0.6	35.95
AL	31	2nd	57.62	2.37	0	4.37	33.67	215.87	0.19	16.51	1.65	23.16	0.55	28.49
AL	31	3rd	57.75	0.39	0.28	3.08	35.17	264.44	0.15	15.81	1.76	22.2	0.54	24.96
AL	31	4th	59.79	1.07	2.13	3.84	29.3	242.36	0.15	15.63	1.81	19.51	0.55	31.22
AL	31	5th	54.47	1.57	5.11	6.28	29.62	429.4	0.1	15.75	1.93	26.68	0.61	39.04
AL	32	1st	41.94	4.5	0.02	2.62	48.83	791.55	0.07	17.95	1.89	33.24	0.58	25.96
AL	32	2nd	38.22	4.07	0.02	1.8	53.93	1203.12	0.05	17.29	2.28	37.46	0.56	23.84
AL	32	3rd	37.47	3.1	0	2.06	55.82	1912.55	0.03	17.33	2.43	37.3	0.55	22.37
AL	32	4th	33.61	1.73	0	1.61	61.86	2300.37	0.03	16.42	2.27	41.5	0.5	19.94
AL	32	5th	28.03	1.05	0	4.61	64.53	4411.97	0.02	14.91	2.71	48.56	0.5	23.17
AL	34	1st	26.2	0.58	0.4	12.08	59.56	2778.48	0.03	9.7	1.89	64.29	0.56	32.17
AL	34	2nd	22.24	0.78	0.41	16.37	58.96	3481.4	0.02	8.56	1.81	70.19	0.58	31
AL	34	3rd	17.12	0.54	0.16	20.86	60.13	3813.9	0.02	7.11	1.73	75.47	0.57	34.3
AL	34	4th	14.14	1.35	0.15	25.4	58.4	13313.93	0.01	5.65	2.41	80.01	0.57	31.69
AL	34	5th	21.1	1.72	0.35	20.31	55.76	3613.69	0.02	7.41	1.86	74.62	0.6	32.28
AL	35	1st	6.79	3.47	0	75.9	10.39	13671.6	0.01	6.39	2.7	76.73	0.41	45.85
AL	35	2nd	9.05	5.85	0	61.07	20.01	5611.42	0.02	6.44	1.93	77.23	0.57	50.68
AL	35	3rd	9.24	6.06	0	48.7	31.97	13514.4	0.01	6.65	2.54	76.39	0.65	52.94
AL	35	4th	8.71	4.29	0.13	48.9	34.71	13666.4	0.01	7.38	3.21	75.19	0.63	49.74
AL	35	5th	15.21	0	0.13	35.84	45.51	9536.06	0.01	10.02	2.87	66.09	0.64	43.21

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt #	Partial PART	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	1	1st	38.7	0.48	16.39	0.42	24.23	287.34	0.14	14.54	1.67	29.81	0.75	48.54
AL	1	2nd	54.8	1.23	12.84	0.44	16.02	148.62	0.21	13.19	1.52	20.06	0.65	47.96
AL	1	3rd	57.78	0.86	10.37	1.03	20.46	199.74	0.16	12.17	1.57	27.62	0.61	40.23
AL	1	4th	47.77	0.74	2.03	2.23	39.14	337.7	0.13	10.39	1.55	50.86	0.61	35.69
AL	1	5th	25.82	0.14	5.87	1.97	54.79	969.56	0.06	8.37	1.57	67.97	0.62	38.81
AL	22	1st	57.84	0	2.46	1.81	35.32	546.67	0.07	11.37	1.68	36.08	0.54	30.77
AL	22	2nd	51.68	0.2	2.5	2.64	39	768.1	0.06	12.41	1.82	35.76	0.58	32.13
AL	22	3rd	46.21	0.83	2.28	2.2	43.34	864.19	0.06	12.43	1.76	40.1	0.6	36.77
AL	22	4th	37.26	3.38	2.84	6.24	42.92	1078.99	0.05	13.2	2.04	43.36	0.67	46.49
AL	22	5th	27.39	4.61	4.06	9.95	46.91	1499.74	0.04	12.81	2.01	53.36	0.69	51.51
AL	23	1st	8.08	0	0.48	0.08	89.93	13416.87	0.01	4.79	2.28	81.72	0.18	27.16
AL	23	2nd	6.87	0	0.77	0	91.06	39067.41	0	4.22	3.54	83.6	0.17	35.97
AL	23	3rd	7.5	0	2.69	0	89.32	14076.76	0.01	4.12	2.58	83.95	0.2	26.6
AL	23	4th	11.57	0	2.9	0.45	83.63	7862.56	0.01	5.8	1.94	79.27	0.29	28.03
AL	23	5th	11.19	0.03	3.08	0.82	83.03	9958.85	0.01	6.06	2.25	78.24	0.3	30.16
AL	24	1st	49.86	0.23	1.44	6.24	41.13	446	0.11	12.01	1.64	45.31	0.58	28.03
AL	24	2nd	40.4	0	0.41	10.81	47.35	961.78	0.06	11.67	1.8	51.66	0.6	27.93
AL	24	3rd	35.49	0	0.07	11.04	52.59	1530.18	0.04	12.07	2.08	53.03	0.59	22.87
AL	24	4th	30.6	0	0.07	11.94	56.86	1865.95	0.04	11.05	1.87	58.5	0.57	25.12
AL	24	5th	31.4	0.2	0.87	10.44	56.61	1353.19	0.05	11.26	1.79	58.16	0.57	25.89
AL	25	1st	22.61	0	2.46	2.52	69.1	2401.4	0.03	12.87	2.1	55.03	0.47	26.74
AL	25	2nd	30.25	0.16	0.44	2.71	64.24	1292.78	0.05	15.28	2.02	45.39	0.49	22.88
AL	25	3rd	33.04	0.24	0	3.22	60.75	833.21	0.08	15.64	1.89	43.78	0.52	25.06
AL	25	4th	25.77	0.2	0	2.9	66.3	1167.56	0.06	13.86	2.08	53.58	0.49	31.69
AL	25	5th	15.18	0.19	0.16	1.89	76.95	2048.97	0.04	11.04	2.11	64.71	0.38	34.55
AL	26	1st	32.83	0.11	0.24	2.38	58.83	626.33	0.1	13.67	1.8	48.68	0.54	31.33
AL	26	2nd	33.45	1.4	0.78	2.14	56.44	635.81	0.1	13.45	1.85	50.25	0.57	38.88
AL	26	3rd	33.62	2.66	2.68	1.4	48.08	500.94	0.11	13.3	1.81	49.1	0.65	51.23
AL	26	4th	34.4	2.7	2.93	0.98	50.68	767.36	0.07	14.45	2.09	43.67	0.62	46.57
AL	26	5th	36.71	2.32	2.85	0.61	53.75	815.48	0.07	13.88	1.91	45.92	0.57	38
AL	28	1st	11.16	0.38	6.76	20.49	46.15	1696.26	0.04	11.18	1.97	60.96	0.72	62.72
AL	28	2nd	16.33	0.38	8.75	13.11	51.6	1313.02	0.06	11.12	1.96	62.85	0.68	53.07
AL	28	3rd	20.7	0	8.95	11.53	54.14	1412.07	0.05	10.73	1.66	63.36	0.64	44.57
AL	28	4th	23.48	0	5.62	11.29	57.45	1785.47	0.04	10.47	1.71	62.14	0.6	39.67
AL	28	5th	27.51	0	1.68	8.4	59.97	1401.06	0.05	11.38	1.66	58.28	0.56	33.82

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt	Partial	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#	PART						(ha)	(no/	(m/ha)		(%)		(%)
									100 ha)					
AL	36	1st	13.31	0	0	7.26	77.56	9715.45	0.01	6.91	2.36	74.52	0.38	33.28
AL	36	2nd	8.03	0	0	6.19	83.62	10390.98	0.01	4.88	2.11	81.32	0.29	37.8
AL	36	3rd	11.8	0	0.32	5.11	79.76	7917.89	0.01	4.92	1.79	81.84	0.35	39.33
AL	36	4th	19.52	0.33	0.33	2.84	70.79	3086.99	0.02	6.76	1.76	73.6	0.46	41.5
AL	36	5th	25.51	0.36	1.18	3	62.17	1929.41	0.03	9.37	1.88	63.33	0.55	41.38
AL	37	1st	3.53	27.2	0	6.29	59.76	5441.25	0.02	5.05	1.75	82.57	0.56	54.88
AL	37	2nd	3.13	20.24	0	9.5	64.76	6206.69	0.02	3.74	1.71	85.82	0.53	51.3
AL	37	3rd	8.12	15.85	0	8.53	63.14	6775.79	0.01	4.8	1.94	82.62	0.56	48.18
AL	37	4th	13.8	19.1	0	5.08	56.54	12433.51	0.01	7.49	3.17	72.48	0.62	45.09
AL	37	5th	16.17	16.48	0	7.22	55.45	9039.47	0.01	8.58	3.01	68.55	0.63	42.74
AL	38	1st	22.7	0	0	14.71	60.36	3093.54	0.02	11.53	2.19	60.21	0.56	32.46
AL	38	2nd	17.35	0	0	10.11	70.22	3376.09	0.02	9.42	2.06	68.44	0.47	35.62
AL	38	3rd	15.56	0	0	9.53	72.26	3431.36	0.02	7.22	1.76	75.91	0.44	41.83
AL	38	4th	20.54	0.06	0	18.79	57.56	2037.16	0.04	6.55	1.56	76.99	0.59	42.79
AL	38	5th	24.96	0.07	0	24.85	46.97	2019.49	0.04	6.35	1.55	75.99	0.65	45.84
AL	41	1st	15.23	5.13	0	15.96	15.67	357.39	0.1	11.7	1.8	36.38	0.86	69.46
AL	41	2nd	14.17	5.3	0.09	7.77	25.45	353.83	0.11	11.42	1.82	41.34	0.86	70.97
AL	41	3rd	16.06	4.03	0.08	3.82	25.07	460.78	0.07	9.43	1.87	43.68	0.83	68.06
AL	41	4th	6.65	1.45	0	1.74	15.49	301.15	0.06	5.86	1.75	40.27	0.71	72.07
AL	41	5th	0	0.74	0	1.7	7.55	513.54	0.02	2.29	1.79	44.13	0.42	73.85
AL	43	1st	6.07	0	0.21	1.68	87.05	41273.76	0	6.55	5.22	77.03	0.24	42.05
AL	43	2nd	6.01	0	0.21	0.76	89.12	10198.21	0.01	6	2.09	78.37	0.2	44.85
AL	43	3rd	6.62	0	0.49	0.93	86.56	20300.5	0	6.93	3.69	75.8	0.25	46.51
AL	43	4th	6.65	0	0.76	0.53	83.32	7455.73	0.01	8.28	2.96	71.26	0.3	47.55
AL	43	5th	5.51	0	0.28	0.93	85.21	9958.25	0.01	7.64	2.69	73.6	0.27	47.81
AL	44	1st	2.19	0	0	0	51.17	1682.17	0.03	10.09	2.18	51.28	0.63	57.74
AL	44	2nd	1.39	0	0.07	0	39.24	1051.7	0.04	9.18	2.23	45.29	0.67	55.58
AL	44	3rd	2.13	0	0.61	0.73	33.74	661.59	0.05	8.7	2.14	44.13	0.7	57.94
AL	44	4th	3.43	0.02	1.13	0.83	40.12	1005.58	0.04	8.14	1.91	53.46	0.7	59.15
AL	44	5th	7.39	0.29	1.12	1.96	50.88	1579.77	0.03	8.95	1.92	58.82	0.67	60.94
AL	4	1st	17.44	0	0.73	3.32	60.47	1213.21	0.05	12.71	1.86	49.81	0.58	41.7
AL	4	2nd	23.05	0	0.87	2.53	64.58	1121.39	0.06	14.36	1.76	47.85	0.52	35.76
AL	4	3rd	29.31	0	0.68	2.25	65.94	1610	0.04	13.18	1.86	50.69	0.48	25.24
AL	4	4th	35.11	0	0.5	1.94	61.41	1094.24	0.06	13.73	1.73	46.91	0.5	19.57
AL	4	5th	46.27	0.11	2.2	1.28	48.89	568.48	0.09	12.53	1.55	43.88	0.55	24.62

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt #	Partial PART	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
AL	5	1st	51.84	0	0	0.53	46.81	292.55	0.16	16.57	1.73	29.34	0.51	12.32
AL	5	2nd	48.28	0	0	0.27	50.4	466.86	0.11	16.75	1.72	30.13	0.51	12.89
AL	5	3rd	48.27	0	0	0.09	50.32	423.41	0.12	17.08	1.73	27.65	0.51	13.37
AL	5	4th	48.52	0	0	0.19	50	381.18	0.13	16.26	1.67	29.81	0.51	11.71
AL	5	5th	39.39	0	0.1	0.19	58.84	657.69	0.09	14.79	1.68	43.03	0.5	15.8
AL	6	1st	40.28	0.47	3.03	1.52	49.38	664.2	0.08	13.98	1.63	39.32	0.59	33.49
AL	6	2nd	46.66	1.39	2.21	0.96	37.62	396.98	0.11	13.29	1.68	30.3	0.63	40.93
AL	6	3rd	41.59	1.47	2.17	1.34	31.81	315.83	0.12	11.42	1.68	32.78	0.71	53.68
AL	6	4th	39.44	1.8	3.09	1.07	24.28	249.65	0.12	9.29	1.51	32.06	0.76	62.46
AL	6	5th	42.51	2.54	3.57	0.61	16.81	168.35	0.14	8.84	1.55	24.14	0.76	63.29
AL	7	1st	15.5	0	65.27	0	19.04	2748.19	0.03	5.17	1.53	81.73	0.51	40.13
AL	7	2nd	19.67	0	52.37	0.04	27.64	4658.59	0.02	6.16	1.71	77.49	0.61	32.83
AL	7	3rd	28.29	0	34.21	0.08	36.75	2991.98	0.02	6.41	1.65	74.13	0.67	29.88
AL	7	4th	38.09	0.09	21.8	0.04	39.17	876.47	0.07	7.35	1.42	69.28	0.65	27.44
AL	7	5th	42.07	0.09	21.16	0.43	35.2	1111.65	0.05	6.36	1.5	70.81	0.65	31.7
AL	8	1st	32.45	3.44	8.92	4.73	47.92	1597.08	0.04	9.6	1.71	62.24	0.65	41.8
AL	8	2nd	38.71	2.98	4.79	4.09	34.14	600.46	0.08	8.54	1.57	55.17	0.71	46.89
AL	8	3rd	37.22	0	7.53	3.35	31.72	661.86	0.06	8.54	1.65	50.87	0.72	49.86
AL	8	4th	29.99	0	11.02	6.5	32.17	1003	0.05	7.91	1.64	59.42	0.76	53.83
AL	8	5th	21.99	0	14.2	8.03	40.58	1756.25	0.04	7.7	1.66	67.41	0.74	64.36
AL	9	1st	63.11	0	19.18	2.01	14.31	317.02	0.11	8.83	1.52	47.41	0.54	38.93
AL	9	2nd	69.66	0	6.58	2.66	20.8	234	0.13	9.44	1.51	36.59	0.47	27.79
AL	9	3rd	77.56	0	1.77	1	19.37	159.37	0.14	9.14	1.47	20.66	0.36	18.98
AL	9	4th	68.91	0	3.85	1	16.85	176.74	0.12	8.16	1.53	27.05	0.49	38.68
AL	9	5th	57.34	0	9.54	0.81	18.41	221.05	0.13	9.65	1.52	30.88	0.62	49.11
FL	1	1st	31.1	6.89	0	51.35	8.65	1333.27	0.05	10.89	1.69	63.36	0.63	36.7
FL	1	2nd	17.8	12.63	0	59.18	9.26	2513.6	0.03	7.38	1.83	75.83	0.59	37.56
FL	1	3rd	12.14	16.2	0.22	61.51	8.41	3914.64	0.02	6.44	1.84	78.79	0.57	40.59
FL	1	4th	13.51	17.06	0.04	58.17	8.22	3780.09	0.02	7.85	1.92	74.45	0.61	42.32
FL	1	5th	13.07	18.45	0	53.79	7.14	2832.37	0.03	9.44	1.85	69.81	0.65	46.24
FL	2	1st	0.34	4.82	0	28.47	0.01	1509.91	0.02	5.15	2.15	61.5	0.59	60.52
FL	2	2nd	0	3.38	0	20.23	0.61	997.79	0.02	5.01	1.99	51.08	0.52	63.64
FL	2	3rd	0	2.29	0.23	14.06	0.75	252.2	0.07	5.69	1.72	34.74	0.59	67.93
FL	2	4th	0	4.73	0.22	20.12	0.7	281.85	0.09	6.83	1.57	45.29	0.76	67.36
FL	2	5th	0	18.19	0	26.41	3.31	552.73	0.09	5.41	1.45	73.92	0.82	65.96

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt #	Partial PART	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
FL	3	1st	0	1.86	0.12	62.29	12.67	3622.62	0.02	4.17	1.93	84.35	0.58	50.93
FL	3	2nd	0.71	3.68	0	72.38	11.79	10397.96	0.01	3.7	2.12	85.66	0.46	49.56
FL	3	3rd	3.24	2.78	0	76.15	9.7	13946.39	0.01	3.71	2.33	85.24	0.41	46.11
FL	3	4th	7.14	2.95	0.02	71.28	10.69	9999.16	0.01	5.6	2.55	80.27	0.47	50.01
FL	3	5th	15.57	1.83	0.02	64.01	12.65	5279.96	0.01	8.12	2.5	73.93	0.55	47.89
FL	4	1st	32.2	12.87	0	46.67	4.51	1245.46	0.05	14.56	1.99	50.18	0.66	40.42
FL	4	2nd	20.43	15.73	0	57.96	3.2	2243.16	0.03	11.05	2.01	64.02	0.6	38.36
FL	4	3rd	13.12	24.62	0	59.02	1.61	4956.52	0.02	8.13	1.94	72.86	0.57	33.87
FL	4	4th	8.8	28.28	0	59.33	0.22	5862.21	0.01	6.39	1.94	77.56	0.56	34.53
FL	4	5th	4.95	25.43	0	65.08	0.04	6002.61	0.02	4.83	1.88	82.75	0.51	33.8
FL	5	1st	3.12	19.61	0	76.92	0.2	42790.28	0	1.8	2.02	90.82	0.37	18.07
FL	5	2nd	2.06	18.59	0	77.36	1.5	22439.12	0	1.79	1.75	91.38	0.37	20.84
FL	5	3rd	2.11	17.42	0	76.03	1.74	14465.63	0.01	2.79	1.88	88.97	0.39	27.38
FL	5	4th	2.96	13.73	0	72.23	4.05	21023.62	0	4.64	2.76	83.22	0.46	40.57
FL	5	5th	3.02	9.3	0	69.1	9.87	8004.02	0.01	5.25	2.07	82.06	0.5	47.6
FL	6	1st	30.71	2.99	0	54.2	3.35	1081.26	0.06	16.87	2.07	39.4	0.61	35.52
FL	6	2nd	27.75	1.67	0	54.86	3.07	896.34	0.07	18.84	2.11	34.34	0.62	42.06
FL	6	3rd	21.98	0.42	0	52.81	3.99	685.68	0.08	18.82	1.95	33.14	0.66	48.62
FL	6	4th	17.28	1.42	0	56.37	4.75	1002.85	0.06	16.43	1.96	45.14	0.64	48.47
FL	6	5th	18.61	2.62	0	55.36	6.47	1412.58	0.05	15.55	2.03	48.89	0.65	46.18
FL	7	1st	2.36	24.36	0.09	68.31	3.33	10942.23	0.01	2.39	1.48	89.33	0.47	33.56
FL	7	2nd	3.44	22.56	0.09	56.55	15.3	8845.88	0.01	3.58	1.7	85.68	0.6	41.79
FL	7	3rd	8.64	21.96	0.09	38.86	28.53	3479.62	0.03	6.88	1.67	78.63	0.71	46.23
FL	7	4th	12.8	23.62	0.09	22.15	39.62	4774.96	0.02	9.75	2.25	70.27	0.72	44.94
FL	7	5th	15.18	24.49	0	13.86	44.15	3615.7	0.02	11.43	2.55	65.11	0.7	45.98
FL	8	1st	5.48	28.15	0	48.4	13.59	6831.87	0.01	6.05	2.16	81	0.66	45.19
FL	8	2nd	5.47	23.34	0	47.9	18.87	5082.86	0.02	5.64	1.95	82.76	0.68	43.2
FL	8	3rd	4.24	13.35	0	58.03	21.81	7188.19	0.01	3.66	1.93	87.43	0.6	37.82
FL	8	4th	1.9	7.99	0	68.54	20.37	11285.4	0.01	2.27	1.96	90.44	0.48	29.97
FL	8	5th	4.44	11.24	0	65.27	17	8725.27	0.01	4.82	1.92	83.81	0.53	35.4
FL	9	1st	0	5.68	0	31.5	15.62	3256.06	0.02	3.68	1.78	80.61	0.71	55.91
FL	9	2nd	0	4.64	0	41.28	8.43	3551.25	0.02	4.78	2.05	76.33	0.66	55.63
FL	9	3rd	0	7.84	0	43.71	14.22	3670.33	0.02	5.74	2.29	77.91	0.72	55.13
FL	9	4th	0.06	12.04	0	38.02	11.42	3073.82	0.02	6.77	2.46	75.11	0.77	56.12
FL	9	5th	0.05	13.4	0	37.75	15.27	3759.35	0.02	6.25	2.55	77.62	0.77	53.26

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt	Partial	% Ag	% Fw	% Dec	% Ev	% Mx	MPS	PD	ED	MSI	TCAI	SIDI	IJI
	#	PART						(ha)	(no/	(m/ha)		(%)		(%)
									100 ha)					
GA	10	1st	52.13	3.85	15.58	13.85	11.96	470.64	0.1	13.36	1.67	35.53	0.67	47.52
GA	10	2nd	58.25	8.32	15.32	8.57	8.13	415.8	0.1	13.48	1.63	30.91	0.62	46.11
GA	10	3rd	61.77	11.26	12.88	5.56	7.14	238.57	0.15	13.58	1.57	26.24	0.58	45.56
GA	10	4th	59.89	12.43	12.61	4.49	7.95	230.49	0.16	14.64	1.62	23.86	0.6	42.27
GA	10	5th	55.33	10.76	11.98	10.86	8.38	248.07	0.17	15.51	1.66	26.22	0.65	44.45
GA	16	1st	26.83	0.11	12.96	8.47	48.96	2252.58	0.03	9.06	1.65	66.51	0.66	45.56
GA	16	2nd	26.01	0.11	9.71	10.79	49.47	2404.25	0.03	9.84	1.78	63.16	0.67	46.53
GA	16	3rd	28.13	0.22	7.75	11.87	46.12	1319.05	0.05	10.71	1.63	59.47	0.69	47.73
GA	16	4th	29.05	0.17	7.77	13.34	43.49	1254.34	0.05	11.58	1.68	55.46	0.7	47.91
GA	16	5th	31.2	0.18	7.33	14.18	40.66	1385.01	0.05	12.44	1.83	51.39	0.71	47.76
GA	22	1st	42.65	1.82	15.22	6.31	32.45	922.68	0.06	14.33	1.88	40.68	0.69	41.53
GA	22	2nd	39.36	1.67	14.47	6.05	36.26	1182.85	0.05	14.25	1.88	42.97	0.69	44.81
GA	22	3rd	37.64	2.05	12.73	6.85	36.99	1225.34	0.05	15.7	1.84	39.06	0.7	50.36
GA	22	4th	36.23	2.24	10.91	7.62	37.63	1033.91	0.06	17.39	1.99	33.72	0.71	53.25
GA	22	5th	32.2	1.68	9.74	5.72	38.6	566.35	0.1	19.36	1.88	27.72	0.73	55.65
GA	25	1st	64.94	7.81	8.92	10.41	4.51	148.17	0.21	16.13	1.73	14.23	0.55	46.43
GA	25	2nd	65.62	5.47	7.74	11.58	5.37	106.1	0.28	16.11	1.65	13.61	0.54	46.83
GA	25	3rd	64.63	3.71	4.99	16.37	6.8	117.27	0.27	15.23	1.56	17.1	0.55	43.65
GA	25	4th	63.04	1.67	3.56	22.83	6.9	164.51	0.21	13.46	1.54	24.66	0.54	38.29
GA	25	5th	62	0.23	1.98	26.21	8.34	237.19	0.15	12.34	1.54	30.3	0.54	32.16
GA	26	1st	22.71	0	41.46	21.03	13.48	2622.96	0.03	6.26	1.75	76.03	0.71	51.75
GA	26	2nd	31.48	0	21.94	21.28	20.47	1679.67	0.04	8.8	1.9	63.72	0.76	51.34
GA	26	3rd	45.06	0	8.87	11.91	27.57	641.17	0.08	10.69	1.68	46.28	0.7	52.75
GA	26	4th	40.79	0	8.58	6.74	36.64	722.5	0.07	9.99	1.7	53.21	0.69	52.95
GA	26	5th	27.11	0	7.84	8.74	49.28	1457.82	0.05	8.75	1.78	65.67	0.67	53.46
GA	28	1st	51.28	0.2	0.1	28.09	16.71	647.65	0.07	11.11	1.78	45.57	0.63	39.4
GA	28	2nd	62.82	0.68	0.1	18.48	15.02	304.05	0.11	11.48	1.73	33.24	0.55	41.29
GA	28	3rd	72.01	0.93	0	11.98	12.41	170.85	0.15	11.37	1.68	16.33	0.45	36.86
GA	28	4th	69.89	1.61	0	12.71	13.62	214.88	0.13	11.58	1.65	19.12	0.48	37.02
GA	28	5th	63.73	3.83	0.1	14.35	13.01	228.84	0.14	11.88	1.64	23.6	0.55	38.68
GA	33	1st	37.26	6.96	6.62	8.69	34.33	1005.69	0.06	12.01	1.9	48.77	0.73	53.04
GA	33	2nd	43.15	7.17	4.42	8.33	29.35	627.96	0.08	11.97	1.66	43.19	0.71	52.92
GA	33	3rd	52.9	5.78	10.41	7.48	16.02	412.54	0.1	12.06	1.68	33.51	0.67	53.98
GA	33	4th	56.54	4.19	12.84	7.37	12.06	276.89	0.13	12.03	1.59	30.4	0.64	51.6
GA	33	5th	52.61	4.4	13.34	8.73	14.86	471.33	0.09	11.93	1.63	35.51	0.67	50.62

Table C4. (cont'd) Value of each of the 12 metrics for each study site for Extent 4.

State	Rt #	Partial PART	% Ag	% Fw	% Dec	% Ev	% Mx	MPS (ha)	PD (no/ 100 ha)	ED (m/ha)	MSI	TCAI (%)	SIDI	IJI (%)
GA	36	1st	39.52	0.02	7.92	7.32	43.19	565.69	0.1	17.54	1.88	37.41	0.65	37.5
GA	36	2nd	29.65	0	8.95	6.63	52.52	892.53	0.08	14.91	1.93	50.8	0.62	44.16
GA	36	3rd	19.64	0.12	11.95	8.49	57.34	2508.72	0.03	12.45	2.15	60.25	0.61	43.4
GA	36	4th	16.01	0.11	14.89	9	57.66	5351.62	0.02	11.06	2.29	63.38	0.61	45.26
GA	36	5th	14.09	0.12	17.11	9	57.56	7527.18	0.01	9.7	2.52	67.51	0.61	46.01
GA	37	1st	21.76	0	17.42	9.55	48.44	4390.13	0.02	8.02	2.01	69.81	0.68	47.39
GA	37	2nd	19.94	0	19.1	7.53	49.87	4952.67	0.02	7.2	1.84	71.6	0.67	49.48
GA	37	3rd	21.89	0	13.09	10.9	50.01	3379.2	0.02	7.5	1.91	71.19	0.67	50.67
GA	37	4th	23.82	0	14.79	12.84	44.62	5564.87	0.01	7.48	2.14	70.56	0.7	47.87
GA	37	5th	23.48	0	16.25	11.47	46.19	4925.8	0.02	6.87	1.9	72.65	0.69	46.64
GA	38	1st	18.84	3.93	0.81	7.42	67.64	3337.27	0.02	7.95	1.67	70.59	0.5	39.09
GA	38	2nd	24.11	3.17	1.56	13.89	55.69	3468.93	0.02	10.01	1.83	62.28	0.61	39.89
GA	38	3rd	22.08	2.77	1.48	28.35	44.27	3996.52	0.02	9.3	1.96	65.56	0.67	40.87
GA	38	4th	23.38	2.86	0.98	44.26	28.04	3555.57	0.02	8.82	1.75	67.09	0.67	38.92
GA	38	5th	21.12	5.21	1.22	50.75	19.78	6022.11	0.01	8.71	2.33	67.21	0.66	45.01
GA	6	1st	34.78	0	2.78	39.65	18.33	1180.04	0.05	12.45	1.85	50.32	0.69	44.31
GA	6	2nd	40.15	0	1.53	33.81	22.55	1033.74	0.06	12.75	1.88	47.04	0.67	36.34
GA	6	3rd	44.19	0.07	5.71	20.93	26.19	679.57	0.08	13.78	1.66	39.7	0.69	39.4
GA	6	4th	42.32	0.07	6.74	16.27	28.99	636.17	0.08	13.48	1.54	40.5	0.71	48.17
GA	6	5th	32.82	0.15	6.08	24.66	31.38	933.26	0.07	10.89	1.49	58.27	0.73	48.07

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14. ABSTRACT

Habitat fragmentation is a major factor in the decline of biological diversity and is an example of how changes in spatial parameters of a habitat can impact species survival. The degree to which a given species is affected by habitat fragmentation is dependent on the complex interaction of the habitat requirements of the species and the shape, size, and makeup of the fragmented habitat. Conservation of the biological diversity of a landscape would be facilitated if there was a way to determine the impact of habitat changes on species of interest. The objective of this study was to use existing U.S. Geological Survey (USGS) Land Use Land Cover (LULC) and the Breeding Bird Survey (BBS) data from the 1970-1976 time frame to determine if kilometer-resolution horizontal spatial pattern metrics are suitable indicators of habitat suitability for conservation birds. The study included 15 conservation bird species with 53 BBS routes per species. It focused on using existing data in predicting bird abundance and evaluating the sensitivity of predictive models to varied sizes of landscape analysis units.

Landscape structure was quantified using 12 spatial pattern metrics calculated from USGS LULC data. The metrics were summarized into three unique variables using principal components analysis techniques. Multiple regression analyses of bird abundance, as a function

(Continued)

15. SUBJECT TERMS

Birds	Habitat composition	Landscape ecology	Spatial pattern metrics
Breeding bird survey	Habitat configuration	Landscape metrics	
Fragmentation	Habitat suitability	Landscape pattern	

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of the three variables, were used to explore the sensitivity of each bird species to landscape structure at various distances from the BBS route. Variables computed from the nearest distance were the most useful. Five of the species studied had models with R^2 values greater than 35 percent. Of these, the wood thrush, Kentucky warbler, and prothonotary warbler, were sensitive to the habitat composition and forest configuration variables, while the hooded warbler and white-eyed vireo were sensitive to the forest configuration and landscape diversity/interspersion variables.

This study has challenged the common view that BBS data can be used only for trend analysis. This study has shown that spatial pattern metrics developed from kilometer-resolution data can provide a good first approximation for assessing habitat suitability. It provides a valuable technique for assessment of habitat suitability and the development of broad-scale conservation management practices.